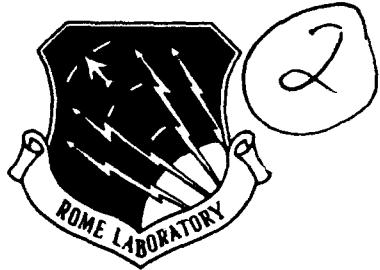


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RL-TR-93-163
Final Technical Report
August 1993



DATA & ANALYSIS CENTER FOR SOFTWARE

Kaman Sciences Corporation

James J. Reed

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This document discusses and describes the operation and maintenance of the Data and Analysis Center for Software (DACS), a Department of Defense (DoD) Information Analysis Center. The report outlines the CCRE operations and technical area tasks performed. The enhanced activities and products and services provided to the DACS user community are discussed.			
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1.0 INTRODUCTION

1.1 Background

In the early 1970's the United States Air Force recognized a need to establish a center to serve as a focal point for software engineering and software technology information and software experience data. The center would ideally serve the combined technical needs of the government, industry, and the academic communities. In 1976, The Rome Air Development Center (RADC), now Rome Laboratory (RL) contracted the design of a center tasked to acquire, store, analyze, synthesize, and report software engineering/technology information. In 1978, RL contracted the development of the center, to be named the Data & Analysis Center for Software (DACS).

In January 1981, the DACS achieved status as a Department of Defense Information Analysis Center (DoD IAC), while still in its test period. A primary goal of the change in status was to transition the DACS from a U.S. Air Force Rome Air Development Center (now Rome Laboratory program to a DoD information resource.

The originating contractor, IIT Research Institute, operated the DACS until the award of this three year contract, F30602-89-C-0082, in 1989. This report describes the activities and actions of the current DACS contractor during the period of performance of this contract, 1989 - 1992.

1.2 Objectives

Primarily, the DACS was established with the goal to serve as a focal point for the defense software engineering community for issues involving software development and the collection of experience data relating to software engineering efforts within the DoD. To achieve the goal, the DACS statement of work requires the DACS contractor to provide software engineering expertise to the defense community; collect, analyze, synthesize and disseminate software engineering data; collect and report scientific and technical information (STINFO) within the field; and provide the community with a centralized authoritative source for current and readily available software engineering information.

The DACS is organized to meet the objectives outlined above through the following:

- Providing products and services to the defense community to aid in the software engineering technology transition and transfer.
- Support for software technology transfer through conferences and workshops aimed at dissemination and exchange of existing information and developmental technology.
- Making software engineering project, tool, and life cycle data available to DACS users.
- Analyzing software engineering data and providing that analysis to the requesters and to other users as appropriate.
- Providing information transfer to our users through publications such as the DACS Newsletter and periodic bulletins.

- Preparing technology reports describing the state-of-the-art and practice of selected software technology areas.
- Preparing critical reviews and technology assessments to take a more in-depth look at selected software engineering technology areas.
- Conducted research into various aspects of software engineering to improve methods, performance, suitability, quality, and reliability of software.
- Minimizing duplication of software research and engineering through program review and coordination efforts.
- Providing technical and engineering assistance to DACS users for the solution of questions and problems concerning software engineering/technology issues.

To meet the general goals and objectives of the DACS, the Kaman Sciences Corporation team developed several goals which it pursued during the performance of this contract. They are as follows:

- Increase the visibility of the DACS as a software engineering resource available to the defense community.
- Enhance the STINFO program holdings.
- Improve the type and level of products and services available to the users.
- Provide cost effective operation of the DACS in an era of research and development expansion but with the limited resources available for DACS operation.

In the remaining sections of this report, we will highlight the various aspects of the DACS Charter and the successes and lessons learned through Kaman's initial contract as the DACS operator.

1.3 Contents

This report is divided into 11 sections. The following lists each section and provides a brief description of the contents:

- Section 1.0 Background, goals and objectives of the DACS.
- Section 2.0 General operations of the DACS.
- Section 3.0 Description and discussion of the scientific and technical information program
- Section 4.0 Discussion of the data acquisition efforts for the period.
- Section 5.0 Description of the data analysis program conducted during this contract.

- Section 6.0 Technical reports produced during this contract period.
- Section 7.0 Summary of the information transfer efforts within the DACS.
- Section 8.0 Description of new products and services available from the DACS.
- Section 9.0 Promotional efforts made to increase DACS visibility.
- Section 10.0 Technical area task summaries.
- Section 11.0 Lessons learned and recommendations for the future.

2.0 DACS OPERATIONS AND MAINTENANCE

Throughout the performance of this contract, Kaman Sciences Corporation sought to apply the highest level of software engineering talent available to solve problems brought forward in the software engineering community and to provide top-level products and services to our users. The DACS staff, enhanced by the presence and availability of numerous Kaman employees and a strong subcontracting team, provided thorough coverage of the software engineering disciplines and effective solutions to the needs of the defense software engineering community.

Efforts were expended to increase the quality and quantity of our services, enhance the level and type of products and services we provided and increase the visibility of the DACS within all areas of the software engineering community. To accomplish our plans to upgrade the capabilities and reputation of the DACS we pursued a number of activities.

Technical reports in the form of state-of-the-art and critical review/technology assessments were produced on topics of major interest to members of the defense community. (See section 8.0 for a discussion of the technical report products.) While many of the reports were prepared by members of the DACS staff, other reports were prepared on a sub-contracted basis, with industry and academic leaders in the software field.

We added substantial numbers of software engineering abstracts and citations from software engineering and software technology papers, proceedings, books and other printed source material. Approved citations increased from over six thousand approved citations produced in the first ten years of DACS existence to more than thirteen thousand citations at the end of this contract. We added citations from newly available material as well as filled in missing citations of important material from the mid-1980s to the present. We also reversed the trend in adding citations without having the corresponding source material also available. Important publications, books and proceedings as well as other supporting printer matter were again added to the DACS holdings as well.

The DACS staff provided expert scientific and engineering assistance in solving a wide variety of special studies for our users. We were able to serve not only the traditional customers of the DACS but were able to attract a number of new customers as well.

Upgrades to the DACS Newsletter, published quarterly, proved very popular with the DACS user community. In a survey of our subscribers, one of the most frequent comments was that the

improved format, increased readability of technical articles and general content was a positive incentive for customer use of the DACS and its products and services.

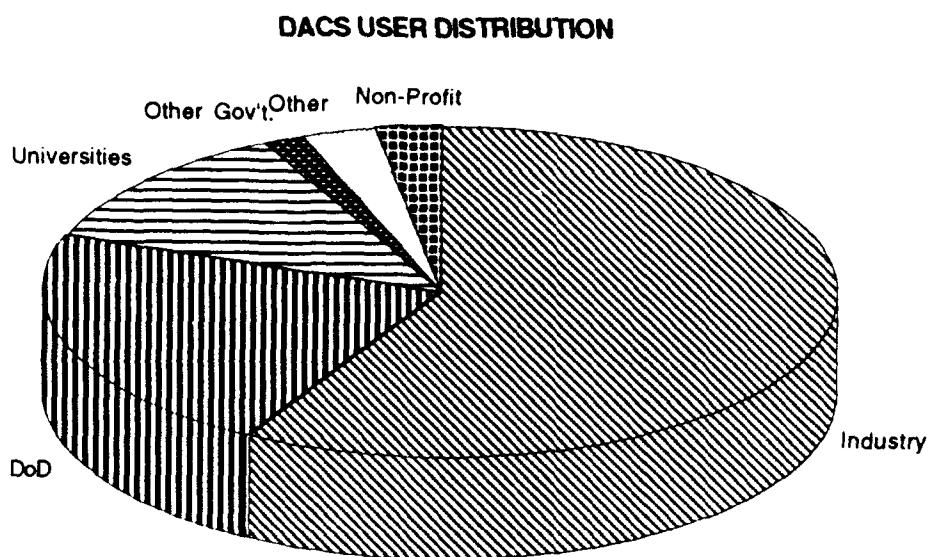


FIGURE 2.0 DACS USER DISTRIBUTION

To increase the visibility, recognition and reputation of the DACS we increased our involvement with high-level activities whose goals included long term software engineering planning and specification. The DACS staff actively supported efforts involved with the following:

- DoD Software Action Plan
- DoD Software Technology Strategy
- Standards and Specifications Identification, Selection, and Recommendation
- Militarily Critical Technologies List Planning
- Navy Next Generation Computer Resources Program
- National Organization Support (e.g., IEEE, ACM, AIAA, etc.)

Through our efforts we directly supported the Defense Science and Technology Strategy for maintaining military technology superiority. We participated in key research and development areas that included artificial neural networks, distributed and parallel processing in heterogeneous and homogeneous environments, signal processing algorithms, software image processing, risk assessment, the development and use of artificial intelligence tools and techniques, and software producibility measures.

The DACS also provided support for Desert Storm and Desert Shield through performance of special studies. The DACS has conducted a series of special studies for the U.S. Army Armament, Munitions, and Chemical Command (AMCCOM) investigating the use of application programming environments within the context of open systems architecture. The result of these studies has been the development of a prototype advanced technology office automation system which uses a commercial off-the-shelf programming system in conjunction with relational databases to provide a highly portable, easy to maintain, user friendly tool for the Army. It is planned during the next DACS contract to make the tools developed by Kaman personnel available as products through the DACS.

The prototype Technical Data Package Tracking and Reporting System, known as the TDP TRACKER, automates the generation and transmission of the technical data associated with a procurement package within the U.S. Army Armament, Munitions, and Chemical Command (AMCCOM). The TRACKER handles the automatic consolidation and authorization of the Contract Data Requirements List (CDRL), Document Summary List (DSL), the Statement of Work (SOW), and the on-line query of existing Procurement Work Directive (PWD) data. The system is capable of routing text and image data and has significantly reduced the average response time (from 180 days to less than 40) and improved the quality of technical data packages.

Operating as a distributed processing system, the TRACKER receives input daily from AMCCOM's Commodity Command Supply System in the form of PWDs for which technical data packages may need to be generated. TRACKER parses the PWD images for key words and phrases, and, using rules, distributes these images to those organizations from which input/approval must be obtained. These organizations are located at the Rock Island Arsenal, Rock Island, Illinois and at the Picatinny Arsenal, Dover, New Jersey. Chemical actions are queued for the Chemical Research and Development Center, Aberdeen, Md., but the chemical function is not included in the prototype.

During the Desert Shield/Storm operation, TRACKER handled the non-classified procurement actions for AMCCOM. Numbering approximately 3000, these actions were given special priority codes which grouped them for immediate action within each organization's work queues. Using the TRACKER's distributed query processing, organizations could preview and prepare for items that had not yet reached their organizations, and could perform their required actions as soon as the system routed items to them.

With the close of Desert Storm, the TRACKER provides an easy mechanism for review and cancel of items no longer required, and as a repository of information that could be used for a performance analysis of organizations in the technical data processing loop.

3.0 DACS STINFO PROGRAM

Scientific and Technical Information (STINFO) may include a variety of information categories. At the DACS, we include in STINFO, the abstracts and citations that comprise our **Software Engineering Bibliographic Database (SEBD)**, information and data from software engineering research which we house in the **DACS Software Engineering Research Projects (SERP)** Database, and information on tools and technology developed to solve software engineering and software technology problems. That information is maintained in the **DACS Software Engineering Tools Information (SETI)** Database. While the latter database is not a contractual obligation, we feel that it is important to maintain the information for the convenience of our users.

3.1 Software Engineering Bibliographic Database (SEBD)

The SEBD has been organized, developed and continuously upgraded to insure a readily accessible source of comprehensive, current information is available to the DACS staff and our users on virtually all aspects of software engineering and software technology. The information is routinely accessed in the performance of DACS CORE and Special Study activities. Periodically, the information is accessed by members of our user community as well.

Users may access the data by obtaining printed copies of our annotated bibliographies or through special reports detailing limited sets of information based on key-word identification. Future plans include making the SEBD available via floppy disk in both a PC version and a Macintosh version and making the SEBD fully available to our users via on-line computer access.

The DACS maintains more than 13,000 citations in the SEBD. At the close of the contract 13,608 citations were in the database with 1,190 software engineering key words contained in the SEBD Thesaurus. Data was acquired from a variety of texts, technical reports, professional journal articles, conference and seminar proceedings, academic thesis and papers, and other pertinent printed matter. Entries were made by university student co-op students under the direction of the DACS Librarian and STINFO Manager and by students at Arizona State University, a university noted for an excellent software engineering academic library collection. There are a number of ways to research and access the information contained in the SEBD. Most typically data searches are carried out using key word searches from the DACS Thesaurus.

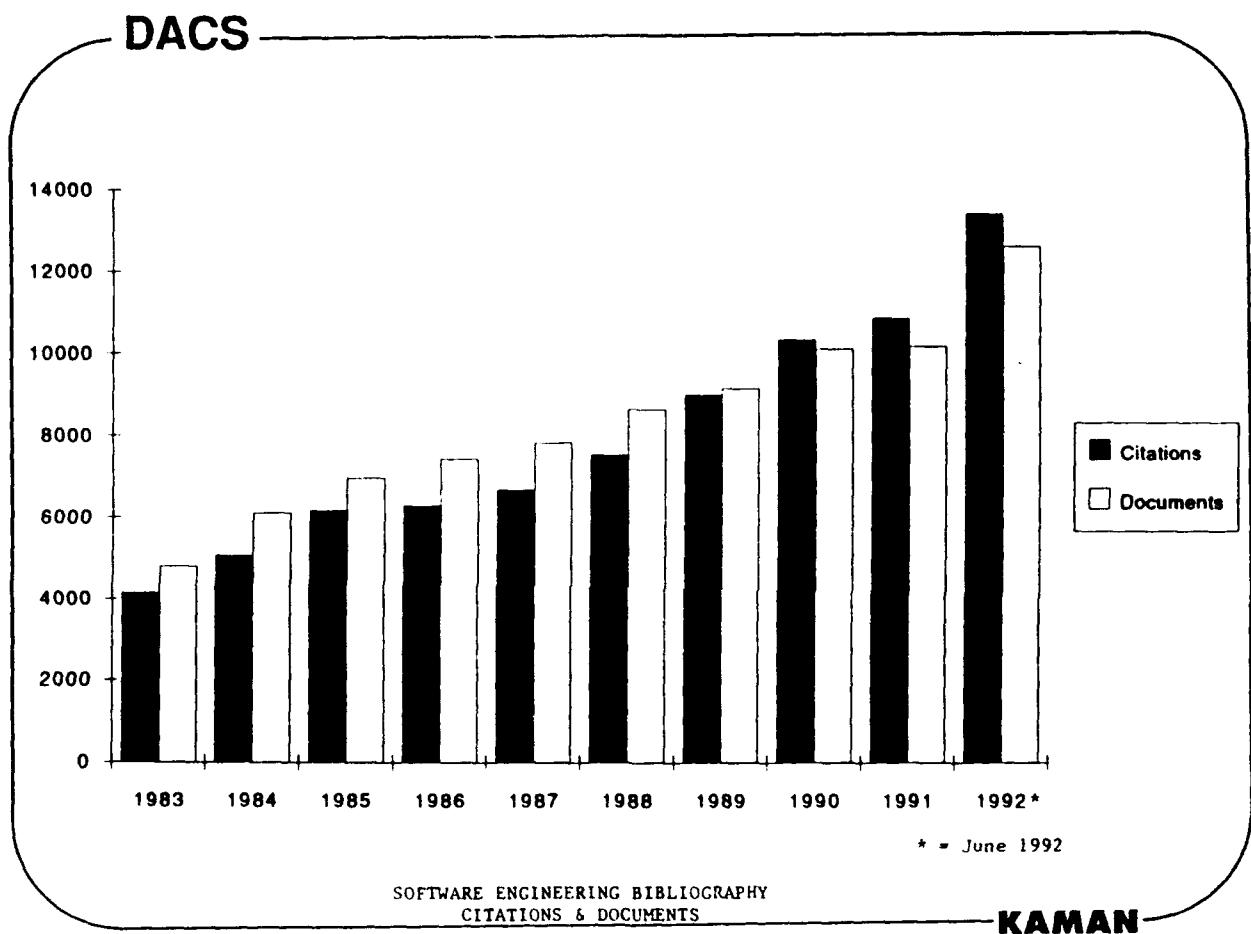


FIGURE 3.1 SOFTWARE ENGINEERING BIBLIOGRAPHIC DATABASE GROWTH

The staff of computer scientists and engineers at the DACS constantly seek to improve the quality and accessibility of the SEBD data. Through enhancement of the input processes, data loading has been improved and the capability to automate error checking schemas was under constant review. A by-product of these efforts was that the time spent in performing clerical tasks was reduced while the quality and accessibility of the SEBD was improved. This area was one of ongoing commitment for KSC.

3.2 Software Engineering Research Projects (SERP) Database

The Software Engineering Research Projects (SERP) Database contains information on past and current research projects which involve software engineering and software technology. Included in the database is a description of the research, identification of the researcher(s), the sponsor of the particular effort, and available information in the following categories

- Goals and Objectives
- Technical Approach
- Task Plans
- Level of Effort
- Status
- Results

Current data in the SERP captures research project data on a variety of software engineering projects involving software programming languages, models and methods, software tool development and application, as well as information relating to modern software programming practices.

The SERP is currently implemented as a collection of hard copy data, a related database acquired during this contract, and third-party data accessible by the DACS. Hard copy reports include 1,400 Work Unit Summaries acquired from the Defense Technical Information Center (DTIC) and 250 citations from *USAF Manufacturing Technology*. DoD project monitors submit Work Unit Summaries to DTIC to prevent duplication of effort on DoD efforts. They contain project information such as period of performance, points of contact, funding level, keywords and descriptors, and a brief verbal summary. The DACS regularly obtains hard copy Work Unit Summaries from DTIC selected on keywords related to software engineering and software technology. DTIC is planning to soon provide Work Unit Summaries on CD-ROM.

The DACS has acquired the Robotics and Artificial Intelligence Database (RAID) during the current contract. RAID contains research project information on robotics and AI-related projects. It is currently implemented as an on-line database at the DACS. RAID development was funded by the Army, the Marine Corps, the Navy, and the Defense Advanced Research Projects Agency (DARPA), with the Naval Ocean Systems Center (NOSC) acting as project monitor. It is designed as a decision support system for program managers and as a technical knowledge base for the researcher in Robotics and AI. The project and contact data stored in RAID is gathered from and verified by a variety of sources, including DTIC, the DoD Manufacturing Technology Program, and researchers in the field. RAID now contains data on over 2,000 research projects and 3,000 points of contact. Government-sponsored DACS users can order reports from RAID, while government personnel can have direct on-line access over Internet. On-line access permits the user to search RAID directly and print the results on his local terminal.

The DACS acquired a CD-ROM reader and established on-line access to the Defense Technical Information Center (DTIC) as a mechanism for acquiring SERP data. In addition, the DACS obtained NASA ASTRO CD, a CD-ROM prototype of NASA's Aerospace and Technical Research database. The CD-ROM contains five years (1988-1992) of bibliographic citations from

NASA/RECON files. Research projects can be identified by DACS staff from NASA ASTRO CD.

A Defense Research On-Line System (DROLS) account was established with DTIC. This account permits DACS personnel direct access to SERP information held at DTIC via modem. Through this mechanism, SERP information can be down-loaded and stored on the DACS computer system for further review and processing.

Plans currently exist to design an on-line SERP database integrated with the other DACS STINFO databases. A database schema for an on-line SERP database was designed early in the contract. Additional SERP information will be acquired via a survey of DoD contractors and sponsors. Several additional sources of SERP data were identified:

- Survey responses direct from the contractor or sponsor,
- 1400 Work Unit Summaries available from the Defense Technical Information Center (DTIC),
- Approximately 370 U.S. universities recorded in the DACS User Profile Database,
- Approximately 3,250 contacts at 874 organizations with 2,154 projects recorded in the DACS Robotics and Artificial Intelligence Database (RAID),
- Information contained in *How to Get it -- A Guide to Defense-Related Information Resources* (DTIC, AD-A201 600), and
- Information obtainable from the Defense Gateway Information System (DGIS).

3.3 Software Engineering Tools Information Database

The Software Engineering Tool Information (SETI) Database is a collection of material containing descriptive information on software engineering tools, including tool function, host computer, target computer, availability/control, and supporting documentation. The SETI can assist managers in locating tools of interest and availability, and in identifying tools with similar functions and features.

The SETI is implemented as a collection of hardcopy reports, vendor-supplied product literature, and automated tools acquired from external sources. Two of these reports were supplied by the previous operator of the DACS. These reports are the *Software Life Cycle Tools Directory* (IIT Research Institute, March 1985) and *A Directory of Air Force Ada & Jovial Software Engineering Tools* (IIT Research Institute, February, 1988).

In October 1989, Kaman Sciences Corporation met with the Software Technology Support Center (STSC) to discuss cooperative efforts for collecting software tool information. STSC personnel explained their current projects and the information they hoped to collect. Resources available through the DACS were explained to the STSC. It was determined that the STSC had greater resources than the DACS and a charter to cover software tools. Since the SETI database was not contractually required for the DACS and to prevent duplication of effort, it was determined at that time that the DACS would not actively collect tool information, although it would cooperate with the STSC. Subsequently, articles appeared in the DACS Newsletter describing STSC activities, and the DACS acquired STSC reports describing software tools.

The decision to reduce the emphasis on software tool data collection was revisited as a result of several DACS Technical Area Tasks (TAT) related to the Army's Software Test and Evaluation Panel (STEP) activities. The studies required the DACS to identify software tools supporting STEP metrics. Acquiring information from the STSC with this specific orientation proved very difficult. Accordingly, the DACS began updating the SETI. The initial results for STEP were documented in *A Survey of Tools for STEP Metric Data Collection* (Kaman Sciences Corporation, March 19, 1992).

Since then, additional tool information has been acquired by the DACS. *Software Analysis and Test Technologies* (Kaman Sciences Corporation and Research Triangle Institute, February 1992), a DACS Critical Review/Technology Assessment, lists information on software testing and analysis tools. Additional tool information can be found in *Testing Tools Reference Guide*, a technical report acquired from Software Quality Engineering. Product announcements and reviews contained in *CASE Outlook*, a quarterly newsletter to which the DACS subscribes, are available. In addition, the DACS acquired *Tool Finder/Plus*, a robust PC-based database of Computer Aided Software Engineering (CASE) tool descriptions, produced by the CASE Consulting Group, Inc.

Planning began to consolidate DACS software tool information into an on-line database integrated with the other DACS STINFO databases. More tool information will be acquired via a vendor survey during the implementation of that database. Several potential providers and sources of SETI data will be explored:

- Approximately 371 U.S. universities recorded in the DACS User Profile Database (UPD).
- Vendor data in the form of surveys and product literature currently in the possession of the DACS for approximately 25 vendors,

- Data files for *ToolCase*, a repository of Computer-Aided Software Engineering Tools, produced by Tennessee Technological University, and
- Information contained in *How to Get it -- A Guide to Defense-Related Information Resources* (DTIC, AD-A201 600).

Figures 3.3.1 through 3.3.4 contain several examples of tool information found in the SETI.

Program Name: **The Analysis of Complexity Tool**

Acronym: **ACT**

Price: Unknown

Hardware/Software Platforms:

Sun, Apollo, HP, NCR Tower workstations, DEC VMS and Ultrix systems, and the
IBM PC

Description:

ACT automatically pinpoints where software is too complex to be reliable and quantifies the number of tests needed. This tool produces flow graphs, complexity metrics, annotated listings, test paths, and test conditions "for a manyear of code in under 8 minutes on an IBM AT." ACT analyzes C, FORTRAN, COBOL, Ada, Pascal, various machine languages, CMS-2, VAX Macro, and design languages. It automates the McCabe Structured Testing methodology described by the National Bureau of Standards Publication 500-99, the baseline testing methodology taught in the McCabe Structured Testing Seminars, and the calculation of cyclomatic complexity.

Figure 3.3.1
The Analysis of Complexity Tool (ACT)

Program Name: ACT/Instrumentation

Acronym: ACT/Instrumentation

Price: PC: \$10,500, Workstation: \$26,500 (single user)

Hardware/Software Platforms:

Sun, HP, IBM(RS-6000), PC DOS, DEC, SGI

Description:

The Analysis of Complexity Tool and the McCabe Instrumentation Tool guide an user through the testing effort, ensuring that one tests not only the sections of code one knows to be changed, but also the sections of code that one might not realize were affected by a change. The Analysis of Complexity Tool is a dynamic version of the Battlemap Analysis Tool and it also specifically:

- 1) Produces the Cyclomatic Metric (number of unit tests).
- 2) Produces design complexity metric (number of integration tests).
- 3) Produces the essential complexity metric (measure of structuredness).
- 4) Produces actual complexity (code coverage).

Figure 3.3.2
ACT/Instrumentation

Program Name: Ada Measurement and Analysis Tool

Acronym: ADAMAT

Price: \$ 10,000 and up (Varies with Platform)

Hardware/Software Platforms:

VAX/VMS (any VAX), Rational, SUN, PC's and UNIX

Description:

ADAMAT provides a highly cost effective way for software engineering organizations to acquire quantitative information for detecting quality problems during the design, implementation, testing and operational phases. ADAMAT provides comprehensive and objective visibility into Ada program development, and, therefore, offers greater assurance of the application of good software engineering practices in Ada; of meeting contract or company established programming standards; of maximum utilization of the important powerful features of Ada.

Figure 3.3.3
Ada Measurement and Analysis Tool

Program Name: **AdaQuest**

Acronym: AdaQuest

Price: \$10,000 + (depends on platform)

Hardware/Software Platforms:

DEC VAX/VMS

Description:

AdaQuest is a set of integrated computer-based software tools which provide computer program test and verification support for the Ada programming language. AdaQuest provides automated assistance during the Code and Unit Testing, CSC Integration and Testing, CSCI Testing, and Maintenance phases of the software life cycle.

AdaQuest performs Ada source code processing, including lexical, syntactic, and semantic analysis. Ada source code that is not in accordance with MIL-STD-1815A is identified by AdaQuest and must be corrected prior to further analysis. Once the Ada source code is syntactically correct, various static and dynamic analyses are available. Static analysis includes (1) multi-mode symbol usage -locates the definition and uses of every symbol denoting an explicitly declared entity, (2) program unit nesting, (3) call dependency, (4) task termination dependency, and (5) static task analysis to identify potential circular deadlock.

For dynamic analysis, runtime execution data is collected by AdaQuest-inserted software instrumentation probes. This runtime information is then used for subsequent post-execution coverage, timing, and tasking activity analysis. As part of dynamic analysis, AdaQuest provides for the translation of manually entered "assertions" into executable code. Assertions are functional descriptions which serve to validate correct program functioning.

AdaQuest

Figure 3.3.4

4.0 DATA ACQUISITION

A major part of the DACS' mission is the collection, storage, analysis, and dissemination of software process and product metric data. Examples of such metrics include fault density, failure rate, productivity, schedule length, complexity metrics, and various quality measures such as the average effort needed to correct a fault. Software metric data is needed to validate certain models intended to aid software managers. Cost, size, reliability, and quality models have all been proposed to assist in predicting and controlling various aspects of the software development process and characteristics of the resulting products. Software metric data is also needed to examine the quantitative impacts of new software technologies such as Computer Aided Software Engineering (CASE) tools, Object Oriented programming, rapid prototyping, Ada, etc. Finally, software metric data is useful for individual organizations in optimizing their process.

The DACS serves as a central repository of software metric data, thereby enabling both researchers and practitioners throughout the Defense community to advance both the state of the art and the state of the practice in software development and maintenance. Software metric data is stored in the Software Life cycle Empirical Database (SLED). The metric data acquisition and analysis aspects of the DACS mission have always been a chronic problem due to the limited availability of significant amounts of current data. A comprehensive data collection and analysis program is characteristic of level 4 (Managed) and 5 (Optimizing) software organizations in the Software Engineering Institute (SEI) process maturity organization. Early results from an SEI survey found that over 85% of several dozen organizations studied were level 1 (Initial), with no organization attaining a level 4 rating or above [Humphrey 88]. This result demonstrates how rarely software organizations collect the data the DACS needs.

Despite these inherent handicaps, the data acquisition program exhibit some definite achievements. A dataset of simulated test data was created for examining the performance of software reliability models. The DACS has worked closely with some organizations initiating software measurement programs:

- The American Institute of Aeronautics and Astronautics (AIAA) Space-Based Observation System Committee on Standards Software Reliability Working Group
- The RL Software Quality Technology Transfer Consortium (SQT2C)
- U.S. Army Software Test and Evaluation Panel (STEP)
- Air Force Space Command (AFSPACEROM)

Our investment in supporting these programs resulted in a small amount of new metric data under this contract and should result in the acquisition of large amounts of data in the future.

In addition, the DACS continues to distribute SLED datasets. Procedures have been put in place to allow clerical personnel to prepare copies of the most frequently demanded datasets. One of these datasets is a major update of the National Aeronautics and Space Administration (NASA) Software Engineering Laboratory (SEL) dataset.

4.1 The Simulated Software Reliability Dataset

A recent DACS Data Analysis Report describes an investigation of software reliability models. The empirical portion of that investigation relied on a simulation methodology developed by the DACS. This simulation methodology allows the examination of software reliability models under known conditions. The DACS has used this methodology to examine the behavior of exponential class software reliability models while varying the quality of debugging and other parameters. The result of this experiment was to demonstrate that typical problems observed in applying software reliability models to real-world data can arise when all model assumptions are fulfilled.

The data used in this experiment is known as the Simulated Software Reliability Dataset. It was generated by simulation and consists of the five files listed in Table 8-1. Because the data was generated for a specific experiment and its general applicability may be doubtful, the Simulated Software Reliability Dataset is not distributed by the DACS, although it is described in the DACS Data Compendium [Kaman 92].

FILE	DESCRIPTION	# OF RECORDS
Simulator Data	Simulator Inputs	300
Test Data	Simulator Outputs	157,500
Program Data	Simulator Outputs	300
Parameter Data	Goel-Okumoto Ideal Parameters	12
Model Data	Goel-Okumoto Estimates	300

Figure 4-1:
Simulated Software Reliability Dataset Files and Records

The Simulator Data file contains the parameters describing each program whose testing was simulated. A formal experiment design was used with twelve different cases of parameters. Within each case, 25 programs were simulated. Although the same parameters described each of these 25 programs in a case, the programs varied in the exact location of bugs, the selection and order of test points input to the program, and the errors made while debugging.

The Test Data file consists of the simulated data. Basically, this data is a list of the results of running 525 tests on each program. A result can be either a success or a failure. One can apply almost any software reliability model to this data.

The Program Data file is also data output by the simulator. This file contains parameters such as the number of bugs in the program and the number of inputs that trigger bugs at the end of testing. One can use this data to examine the accuracy of software reliability model estimates.

A prototypical exponential class software reliability model, the Goel-Okumoto model, was applied to the simulated test data during the course of the experiment described in the data analysis report. The Parameter Data file contains ideal values for the model parameters. These values are based on the parameters input to the simulator and a specific theory for applying the Goel-Okumoto model under imperfect debugging.

The last file, the Model Data file, contains the results of applying the Goel-Okumoto model to the test data. Not all values in this file existed for all programs tested; this condition is indicated by a field in the file. The existence of parameter estimates was based on the time between failures, where time is measured in terms of the number of successful tests between failures. Parameter estimates were actually calculated based on failure count data; the number of failures occurring in every group of fifteen tests was input to the model. How well the model fit the data was assessed by the Kolmogorov-Smirnov goodness-of-fit statistic.

4.2 AIAA Software Reliability Data

In early 1988, the AIAA held the first meeting of the Space-Based Observation System Committee on Standards (SBOS COS). The SBOS COS is developing standards that will help improve reliability, safety, and reusability while reducing life cycle costs for space-based missions, both manned and unmanned. The AIAA has six approved SBOS projects underway, including a Software Reliability Working Group.

The objective of the Software Reliability Working Group is the identification or development of viable software reliability models that permit quantitative assessment of risk and prediction of failure rates. These models will enhance the precision and consistency of the aerospace industry's ability to compute the projected contribution of software to the reliability of its software intensive systems.

The AIAA has established a Blue-Ribbon Panel to study issues in this controversial area comprised of:

- William Farr, Ph.D., Naval Surface Warfare Center
- Allen L. Hankinson, NIST
- Herbert Hecht, Ph.D., SoHar
- Myron Lipow, Ph.D., Hughes Aircraft
- * John D. Musa, AT&T
- Andrea Federoff Sebera, SAIC
- Victor Selman, Sc.D., American University

- Martin L. Shooman, Ph.D., Polytechnic University
- David Siefert, NCR

Additionally, the following people have made substantial contributions to this effort:

- Stephen Kelly, Kaman Sciences Corporation
- Devon Smith, General Dynamics
- Ted Keller, IBM Houston
- Michael Lyu, Ph.D., JPL
- George Stark, MITRE
- George Schick, Ph.D., Aerospace Corporation
- Frank Yap, Lockheed

The working group is developing several products, namely, a software reliability handbook, tool evaluations, comparative studies of reliability data sets, and a software reliability database.

Stephen Kelly of the DACS has actively participated in the development of the software reliability database. This participation includes the writing of several draft design documents and the development at the DACS of a prototype implementation of the database. When the database is populated, it will contain a significant compilation of field-operational software failure data. DACS participation has already resulted in the acquisition of hard copies of collections of Software Problem Reports from several companies. More importantly, the AIAA plans for the DACS to manage the software reliability database. Hence, as the AIAA acquires software reliability data in the coming years, it will be stored at the DACS.

4.3 Software Quality Technology Transfer Consortium Data

The Rome Laboratory (RL) Software Quality Technology Transfer Consortium (SQT2C) is a consortium of industrial organizations with the goal of transitioning software quality measurement into practice, particularly the technology associated with Rome Laboratory Software Quality Framework (RLSQF). Through a series of special studies, the DACS has helped RL begin the SQT2C. The DACS participation in the consortium support team has already resulted in the acquisition of some quality metric data. During the following contract, the DACS plans on acquiring a vastly expanded amount of data from this source.

4.4 STEP Metric Data

The U.S. Army Software Test and Evaluation Panel (STEP) initiatives are designed to improve the software test and evaluation process and implement a standard set of software metrics. STEP was initiated in September 1989 by the U.S. Army Operational Test and Evaluation Command (OPTEC). STEP has developed an implemented three products:

- A standard set of software metrics, supported by a centralized metrics database
- A new Army Pamphlet (DA PAM 73-1, Volume 6) with an improved software test and evaluation process and procedures to implement the metrics set
- Requirements for a new document, the User Functional Description (UFD), to better capture user needs for software development projects.

The metrics effort is supported by the development of a central database for Army-wide metrics data collection. The Army-wide database will be used to track both the status of Army software and the use of the STEP metrics set. The database will also serve as the baseline for validation and improvement of the initial metric set. Through a series of special studies, the DACS has provided support to OPTEC in beginning the STEP program. We have developed a tool for analyzing STEP metric data, hosted a workshop for training in the use of STEP products, and begun setting up an information clearinghouse for STEP information and products. As a consequence of this investment under the current contract, the DACS anticipates storing the STEP metrics database when it is created during the following DACS contract.

4.5 Air Force Space Command Data

Kaman Sciences provides engineering, technical, and software support to the Air Force Space Command (AFSPACERCOM). Currently, the Systems and Software directorate of Kaman Sciences, which supports AFSPACERCOM, is upgrading their SEI software process maturity rating. As a consequence, they are interested in the use of software measurement technology to detect areas for improvement in both their process and products. Through an Internal Research and Development (IR&D) effort, Kaman Sciences has funded the DACS to demonstrate some measurement technology.

This IR&D has resulted in the collection and analysis of certain static source code metrics. This analysis is documented in the last data analysis report produced under the current DACS contract and further described in Section 5.3. This preliminary study should result in the acquisition of large amounts of software metric data under the following contract.

References

[Humphrey 88] Watts S. Humphrey, "Characterizing the Software Process: A Maturity Framework," IEEE Software, Volume 5, Number 2, pp. 73-79, March 1988.

[Kaman 92] Kaman Sciences Corporation, The DACS Data Compendium, April 1992.

5.0 DATA ANALYSIS

Three reports were produced summarizing the data analysis activities under this contract. The report *Linear Software Reliability Models Under Imperfect Debugging* [Vienneau 91] describes an experiment in which simulated software test data was used to examine the behavior of software reliability models under controlled conditions. *DACS Data Analysis Papers* [Kaman 92a] is a compilation of technical presentations and papers given by DACS personnel relating to technologies that provide the software engineering foundation of the DACS data analysis program. *SPADOC Source Code Metrics Application* [Kaman 93] compares and contrasts automatically collected source code metrics from an Air Force Space Command (AFSPACERCOM) with metric information from three other FORTRAN systems.

5.1 Linear Software Reliability Models Under Imperfect Debugging

The report *Linear Software Reliability Models Under Imperfect Debugging* describes the results of an experiment designed under the previous contract [Vienneau 89]. That experiment examined the behavior of software reliability models under the assumption that analysts commit errors while debugging software after testing has detected a fault. A variety of software reliability models have been developed over the last two decades to assist in the specification, measurement, certification, and control of software reliability. A body of knowledge is growing on how well these models can be expected to perform in practice. Empirical applications have uncovered various problems. Numerical methods for parameter estimates frequently diverge. Parameter estimates can seem quite different from true values. Performance measures, such as reliability, can be very variable. This study was designed to investigate the causes of these difficulties.

Exploring the full implications of software reliability modeling assumptions and their violations presents great analytical difficulties. Since many assumptions deal with unobservable, empirical work is also problematic. Thus the opportunity for simulation arises. This study therefore adopted simulation methodology that was previously employed for exploring the effects of relationships between program functions, the locations of bugs, and the selection of test cases on software reliability modeling. The study used this simulation methodology to explore the effects of variations in the locations of bugs, imperfections in debugging, and random testing on the performance of a representative software reliability model when all assumptions are met.

The major conclusion of this study is that the problems observed in practice when applying software reliability models can arise even under these ideal conditions. Programs in which each bug has a small impact on the failure rate can generate data for which the equations defining maximum likelihood estimates fail to have a solution. Parameter estimates tend to be biased with the bias increasing for low reliability programs. Errors in parameter estimates tend to cancel out yielding more accurate estimates of reliability, thus providing empirical support for the assertion that reliability models should be used to control reliability, not bug content. Finally, a previously proposed method of measuring goodness-of-fit was shown to be very inaccurate.

Whether or not the performance of models with more realistic assumptions might be better is a question that future research conducted with this simulation methodology can explore. Likewise, one can examine the less than ideal conditions where some assumptions are violated. Finally, the performance of other estimation methods and goodness-of-fit measures should be explored. The results of this study are presented in detail in [Vienneau 91].

5.2 DACS Data Analysis Papers

As of July 1992, DACS core personnel had presented six papers under this contract treating software metrics, cost models, reliability, and quality measurement. These measurement and modeling technologies provide the software engineering foundation for the DACS data analysis program. The second data analysis report collected these papers under one cover [Kaman 92a]. Each set of slides in the report is accompanied by a section describing the oral deliveries given at the conferences and meetings at which these papers were presented.

The data analysis report contains the following six papers:

1. Robert Vienneau, "STEP Metrics Compared with Previous Programs," Proceedings of the 3rd Annual Software Quality Workshop; Alexandria Bay, New York; August 11-15, 1991.
2. Robert Vienneau, "The Cost of Testing Software," Proceedings of the Annual Reliability and Maintainability Symposium; Orlando, Florida; January 29-31, 1991.
3. Stephen Kelly, "Software Quality Measurement," Software Improvement Conference; Washington, DC; November 29-30, 1990.
4. Robert Vienneau, "Models for Incorporating Software into System Reliability," Society of Automotive Engineers AS-5 Committee Meeting; Santa Barbara, California; July 16-18, 1990.
5. Robert Vienneau, "A General Poisson Type Software Reliability Model," AIAA Working Group on Software Reliability; May 1990.
6. Stephen Kelly, "RADC Work in Software Reliability," AIAA Working Group on Software Reliability; November 1989.

The DACS has presented one other paper dealing with software engineering data analysis since the preparation of this data analysis report:

- Robert Vienneau, "The Consolidated Experience Factory: An Approach for Instrumenting System Engineering," Proceedings of the 1992 Complex Systems Engineering Synthesis and Assessment Technology Workshop, Naval Surface Warfare Center, Silver Spring, Maryland, 20-24 July 1992.

This last paper, "The Consolidated Experience Factory," presents an approach for instrumentation, data collection, analysis, and improvement of the systems engineering process. This approach, the Consolidated Experience Factory (CEF), has been developed by Victor Basili of the University of Maryland in conjunction with the DACS. The CEF was defined for software development and maintenance, but, as the paper shows, the approach is general enough to apply to systems development as a whole.

"STEP Metrics Compared with Previous Programs" examines the software metrics developed by Army's Software Test and Evaluation Panel. This paper compares and contrasts the STEP metrics with other well known metric programs. These other programs consist of the Software Engineering Institute process maturity metric, the Air Force management and quality indicators.

and the Air Force Operational Test and Evaluation Center's program. This paper consists of both text and accompanying slides.

"The Cost of Testing Software" presents a cost model developed by the DACS. This cost model is based on any of many software reliability models and determines the optimal release time for a software system based on the minimization of lifecycle costs. The cost model is explained in terms of certain basic economic principles. For this paper, the report contains both text and hard copies of slides.

The set of slides, "Software Quality Measurement," presents technologies, tools, and processes to evaluate software quality. Technologies discussed include the RL Software Quality Framework, the Software Engineering Institute process maturity model, and various standards, including the draft IEEE Standard for a Software Quality Metrics Methodology. Points of contact are provided for tools implementing quality measurement technologies. This presentation also overviews some RL software quality initiatives.

"Models for Incorporating Software into System Reliability" consists of a collection of slides presenting a tutorial on certain system reliability models. This talk began with an overview of a military standard system reliability program. The emphasis was on models to aid in up front design and evaluation, not on the later testing that most software reliability models support. Two system models that explicitly account for software were examined in detail. First, a block diagram Markov model developed by Hughes was explained. Even for a simple example, this model quickly becomes computationally difficult. Second, a flowchart-based Markov model was presented. Both of these models show how the reliabilities of individual components combine to yield system reliability, but the latter is much more tractable. How to use the second model to allocate a desired system reliability goal to component reliabilities was also discussed. This talk concluded with a list of references for those interested in more details.

The American Institute of Aeronautics and Astronautics (AIAA) Space-based Observation Systems Committee on Standards Software Reliability Working Group is developing a set of recommended practices for software reliability. The DACS has been actively participating in the working group, and the last two papers in the report are part of that participation. "A General Poisson Type Software Reliability Model" presents a single software reliability model that includes many previously developed models as special cases or as approximations to special cases. The paper develops the model, shows how to estimate its parameters, and presents a goodness-of-fit test.

The set of slides, "RADC Work in Software Reliability," overviews past Rome Laboratory research in reliability, particularly software reliability. Related areas, such as quality measurement, are discussed. The DACS role is also discussed.

5.3 SPADOC Source Code Metrics Application

Kaman Sciences maintains a large software system, SPADOC, for the Air Force Space Command (AFSPACEMCOM) at the Cheyenne Mountain Complex. Under this contract, we collected certain source code metrics from SPADOC by use of a FORTRAN static analysis tool, the Source Analyzer Program (SAP). We also began collecting discrepancy data on the SPADOC system, but the discrepancy data was not yet complete enough to be analyzed under

this contract. SPADOC consists of 11,407,020 lines of FORTRAN source code, including comments and blank lines.

The SAP was also used to collect metric data from three reference systems, IRSS/PAAS, ARCREF2, and MMI. The IRSS/PAAS system is a radar and antenna simulation system developed for Rome Laboratory beginning in the late 1970s. The system has undergone two major ports and extensive functional enhancements during its lifetime. Several different teams of engineers developed IRSS/PAAS. The system was originally designed as a batch system and later converted to an interactive system. The version of IRSS/PASS examined under this study consists of 64,959 source lines of code.

ARCREF2 is another radar simulation system developed for Rome Laboratory. It was developed in the 1980s, and is a more typical example of a modern interactive FORTRAN 77 system. ARCREF2 consists of 30,034 source lines of code.

The MMI system is a signal processing test bed with a generic knowledge-based application generator, a Graphical User Interface (GUI) man-machine interface, and application-specific processing modules. The development of the MMI system began in 1990. The software was written in both FORTRAN and C, with the FORTRAN code being in a Ratfor-like preprocessor language. Only the FORTRAN source code, as automatically generated by the preprocessor, was analyzed. The FORTRAN portion of MMI consists of 81,494 source lines.

The IRSS/PAAS, ARCREF2, and MMI systems provided baselines with which we compared and contrasted SPADOC. The distribution of each type of FORTRAN statement (Assignment, Block data, Call, Character, Common, Continue, etc.) was determined for each system. Usage of questionable practices was noted. For example, input and output was not restricted to a few modules in the ARCREF2 system, indicating a potential maintainability problem. SPADOC was compared with each reference system in terms of the distribution of selected metrics. Modules in SPADOC that had metrics values in the tails of these distributions, and are therefore potentially failure-prone and difficult to maintain, were indicated.

This data analysis study demonstrated a technique which can be used to provide significant insight into potential software maintenance problems for very large systems. The technique identifies particular modules which may be error prone. The technique relies on automated data collection and as a result, it is appropriate when a manual examination of the source code is prohibitive due to system size.

The analysis method is not specific to FORTRAN or the metrics used in this report. We believe that the methods developed in this report are usable for an examination of other large software systems phasing into operations and maintenance as part of the Cheyenne Mountain Upgrade.

As a part of our study we recommend that a number of enhancements need to be made to SAP to improve its effectiveness for analyses such as this one.

- SAP should be made more robust
- SAP should be modified to allow additional keywords to be added dynamically
- Several computed metrics need to be verified for correctness
- Additional metrics should be added to SAP

5.4 Data Analysis Activities Related to Special Studies

Certain special studies included the analysis of software metric data. Quality metrics were collected under the Man-Machine Interface Experiment and examined for their ability to predict the effort required to reuse modules in a new system [Kaman 91]. Under the Investigation of the Quality of Signal Processing Software, automated quality metrics were collected and analyzed for certain FORTRAN subroutines [???]. The Ada 9X Implementation Analysis Support study included the collection and analysis of some common static source code metrics for a couple of Ada systems [Kaman 92b]. Under IV&V Support for the Range Control System, quality metric data was collected and analyzed for the requirements phase of a large software project. The metric data on the IRSS/PAAS and ARCREF2 systems with which SPADOC metrics were compared was collected under the IRSS/PAAS/ARCREF study.

Other special studies, although they did not include metric data collection and analysis, relate to the kind of activities conducted under the data analysis function of the DACS. Along with a DACS subcontractor, Dr. Amrit Goel of Computer Software Modeling Associates, we assisted the Army Operational Test & Evaluation Command (OPTEC) in creating a tool for analyzing software metric data to be collected by the Software Test and Evaluation Panel (STEP) program. This assistance was provided under the following special studies:

- Prototype Software Metrics Analysis & Project Management Tool Investigation
- Prototype Software Metrics Analysis, Project Management, & Risk Analysis
- Software Process & Software Metrics User Functional Description
- Software Metrics Tool Support

We assisted RL/C3CB in initiating a program to validate the Rome Laboratory Software Quality Framework, a hierarchical structure of software metrics, by executing the following special studies:

- Software Quality Automated Method Validation: Setup & Support Task
- Software Quality Lab Support
- RL Software Quality Consortium Support

References

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6.0 TECHNICAL REPORTS

The DACS has published a number of state-of-the-art reports (SOARs), critical reviews/technical assessments (CR/TAs), data analysis reports, and other technical reports under this contract. The reports are:

- Software Reusability (a SOAR)
- Distributed Database Technology (a SOAR)
- CASE Technology (a SOAR)
- Artificial Neural Networks Technology (a SOAR)
- Software Analysis and Test Technologies (a CR/TA)
- Object Oriented Design (a CR/TA)
- Software Quality (a CR/TA)
- Requirements Engineering and Rapid Prototyping (a CR/TA)

Software Reusability is a State of the Art report prepared by Valentin W. Tirman Jr., of Productive Data Systems in Monument Colorado. The report describes software reusability as a management problem, not just a technical problem. The advances in US software technology and software reusability are slow at best. The Private Sector is ahead of the DoD in its efforts simply because the software development process is profit oriented, and most programs are still of manageable size. The question of software reusability is a complex one that affects all vendors in software engineering, as well as their clients.

This SOAR addresses a variety of issues, problems, endeavors, and advances, both in the US and overseas. Section 1 provides a report summary. Section 2 looks at the overall problem of what to do about reusability and includes a number of opinions from industry leaders. Section 3, reusability in the US, discusses software libraries, repositories, tools, and issues of cost and quality as related to software reusability. Section 4 examines the progress that the Pacific Rim countries and Europe are experiencing. The software factory approach currently being used successfully in Japan is discussed and explained in some depth. Section 5 discusses some of the problem areas associated with software reusability. Finally, conclusions and recommendations are presented that include a discussion of factors and issues that need to be addressed when considering reusability in the development and maintenance of software.

Distributed Database Technology is a State of the Art report prepared by Ms. Carol Wawrzusin, a member of the DACS staff. It describes a distributed database as a collection of multiple, logically interrelated databases distributed over a computer network. A Distributed Database Management System (DDBMS) is a software system that permits the management of distributed data making the distribution transparent to the user. This report reviews the issues that arise with such systems, surveys current commercially available DDBMS's, and summarizes the state of the art. Although no standards yet exist within this new technology, some guidelines have been provided by C.J. Date, and E.F. Codd. True implementations of general purpose

DDBMS's are only now beginning to emerge in the marketplace. Their implementations with respect to issues of distributed database technology differ markedly.

CASE Technology is a State of the Art Report prepared by Mr. James J. Reed, DACS Director. The report provides a generic definition of CASE as any set of computer-implemented, defined tools and methods employed to assist in the requirements analysis, design, implementation and or maintenance of a software system. While limited in its scope by the size of the CASE technology area, the report does provide a reference for the software engineer and program manager concerning the selection and application of CASE technology, tools and methods to the problems encountered in software engineering. The report also discusses the introduction of CASE technology into an organization as well future directions that CASE technology will likely follow. The topic of CASE tool, technology and implementation methodology is also discussed along with the potential for conflicts due a lack of standardization. The institution of more formalized methods allowed by CASE, at least internal to a particular project is noted, however.

Artificial Neural Networks Technology is a State of the Art report produced by Mr. Dave Anderson and Mr. George McNeill of Kaman Sciences Corporation. The report is intended to help the reader understand what Artificial Neural Networks are, how to use them, and where they are currently being used. Touted as the wave of the future, Artificial Neural Networks are self-learning mechanisms which don't require the traditional skills of a programmer. But the reality is often different from the hype and developers have often come to the conclusion that neural networks are complicated and confusing. In examining several efforts and methods for developing Artificial Neural Networks, examples are cited and the structures are provided. The introduction provides an up-front guide to the reader who wants a simple explanation of the technology and a road map for those who want substantially greater details.

Software Analysis and Test Technologies is a critical review/technology assessment prepared by staff members from the Research Triangle Institute and the DACS. The report examines current software analysis and test technologies and the needs that should be filled by future technology. Analysis and testing of software includes all life cycle activities conducted to verify and validate the software product. These activities are undertaken with the goal of assuring the robustness of the development process and the integrity of the developed product throughout the life cycle. Successful strategies for analysis and test must provide decision support information to the acquisition manager, the certifying agent, and the field engineer. There is a need for quantitative empirical data to demonstrate when and where various techniques are most successful. There is a need for integrated development environments which include analysis and test support. This report also considers improvements in analysis and test required to support trends in formal methods, object oriented development, parallel programming, and system engineering.

Object Oriented Design is a critical review/technology assessment report prepared by Mr. Robert Vienneau of the DACS. The report provides a basic understanding of Object Oriented Design (OOD) and some of its features. The report briefly summarizes the history of OOD, includes a description of an OOD methodology, and defines and discusses various concepts and terminology used in OOD. The level of support that various programming languages provide for OOD is discussed in some detail. Languages covered include Modula-2, Ada, C++, Object C, LISP, Smalltalk, and Eiffel. Section 4 discusses how OOD interacts with areas of current software engineering research, especially software reuse and alternative life cycle models. The report also includes a glossary of OOD terms and an annotated bibliography of related papers and reports.

Software Quality is a critical review/technology assessment prepared by Mr. Valentin W. Tirman, Jr. and Mr. Gene Miluk of Productive Data Systems in Monument, Colorado. The report provides an assessment of the current state of the art and practice concerning software quality. The report is a compilation of where the technology is at currently. It discusses the management aspects of dealing with software quality initiatives, provides an overview of significant work being accomplished in metrics, process improvement and describes work being done overseas. The 175 page report is divided into 12 Sections. Conclusions and recommendations, references and bibliography and computations are all provided in the report.

Requirements Engineering and Rapid Prototyping was prepared by Dr. Joseph Urban of Arizona State University and Mr. James J. Reed, DACS Director. This critical review/technology assessment includes the motivation for using software prototyping in general and specifically in the context of requirements engineering. An overview of software prototyping covers life cycle models, approaches, pitfalls, and opportunities. The chapter on software requirements and specification establishes a basis for investigating techniques. A comprehensive and exhaustive analysis of software requirements and specification techniques and tools for prototyping addresses sixty techniques across a variety of application domains. The analysis includes a summary of common aspects among the techniques. Software technology transfer is addressed in this report from the standpoint of past problems, avenues of opportunity, and actual experience in this area. The report concludes the topic of prototyping and requirements engineering with an assessment of practice, availability, potential areas of research.

7.0 INFORMATION TRANSFER

A primary activity of the DACS involved transferring information from the laboratory or other research environment to the field where it could be applied to solve software engineering problems. We also kept our users informed about the latest developments in the field and the standard, as well as new products and services available to the users from the DACS.

To accomplish those information transfer goals, we have carried out an active current awareness campaign using the tools available to us. They include the following:

- Publication of a quarterly DACS Newsletter
- Publication of a DACS Bulletin
- Participation in the activities of national organizations
- Presentations at events involving software engineering/technology
- Development of contacts within major software engineering-related organizations

7.1 DACS Newsletter

The Quarterly DACS Newsletter was the subject of numerous favorable comments throughout the DACS comments. Most of those comments were targeted toward the enhancements in format and content introduced during the last half of the contract. The length of the newsletter was extended to accommodate more information and added regular features.

Most often cited as favored articles were the software engineering conference summaries, the "Close-up Corner" section which takes a more in-depth look at an aspect of software technology, and details provided about DACS software engineering activities. Also popular was the calendar of upcoming events which was used to announce not only DACS-sponsored activities, but other technical conferences and activities of interest to the community. The DACS Newsletter is a free product. It was provided to more than 7,000 DACS users each quarter. A concerted effort is being made to make sure that DoD and industry leaders receive the DACS Newsletter and are made aware of our capabilities, products and services.

DACS Newsletter

Data & Analysis Center for Software

Data & Analysis Center for Software □ 258 Genesee St., Suite 103 Utica, NY 13502 □ 315-734-3696

DIRECTOR'S NOTES

This month in the DACS Newsletter, we have highlighted the activities of the U.S. Army's Software Test and Evaluation Panel (STEP) Workshop, which was held in Denver, Colorado in February. Hosted by the DACS, the workshop provided in-depth coverage of the Army Operational Test and Evaluation Command's initiative to integrate software test and evaluation principles into the software development process. The OPTEC point of contact for obtaining further information on the STEP initiative is listed on page three.

Also note on page three, the preliminary announcement of the Fourth Software Quality Workshop, scheduled for August 2 - 6, 1992 and in the Upcoming Conferences and Events section, the announcement of KBSE-7, scheduled for September 20 - 23, 1992. This year's KBSE conference will be held in Tysons Corner, VA. These are very popular meetings so make your reservations early.

Several sample bibliographies from the DACS Software Engineering Bibliographic Database have been provided for your examination. The DACS has been adding software engineering citations at a rate of over 500 per month. Within the next several months we will publish several new "hard copy" volumes of the information abstracted. Reminder, we also perform custom searches of our complete bibliography for a small fee. If you have further questions or would like to access our bibliographies, contact Ms. Barbara Radzisz at the DACS, 315-734-3696.

In November 1991 a Computer Aided Acquisition and Logistics Support (CALS) conference and exposition was held in Arizona. While CALS is not strictly a software engineering concern, it does have an effect on us all as a DoD mandated initiative. The DACS supports the CALS initiative in our involvement in several special study areas and in our work with the several DoD components involved with standards and specifications efforts.

In our CLOSE-UP CORNER this month we take a look at various aspects of Software Reliability. If you wish to contribute an article on software reliability or another aspect of software engineering please contact the DACS.

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Figure 7.1 DACS Newsletter

7.2 DACS Bulletin

A variety of DACS Bulletins were prepared and distributed to a limited audience. Primarily, the bulletins were provided to Rome Laboratory personnel with a small number provided outside the Lab to subscription customers and selected others. The bulletins summarized conferences and events within the software engineering community, described new and interesting technology from within the community and described on-going research of interest to bulletin recipients. Much of the utility of the bulletin was lost with the substantial expansion of the DACS Newsletter.

DACS Bulletin

DATA & ANALYSIS CENTER FOR SOFTWARE

DACS Bulletin

Volume IX Number 5

July 1989

COMMON ADA MISSILE PACKAGES UPDATE

Reusable software is often discussed and is a highly sought commodity in the aerospace community. Since its inception in 1984, the Common Ada Missile Package (CAMP) Project, primarily funded by the STARS Joint Program Office, sponsored by the Air Force Armament Laboratory and performed by the McDonnell Douglas Missile Systems Company, has taken a pragmatic approach to demonstrating the feasibility and utility of this concept for real-time embedded systems. CAMP products include 454 operational flight software parts in Ada for tactical missiles, armronics, armament electronics, benchmarks for evaluating Ada compilers, and a prototype parts engineering system to support parts identification, cataloging and construction. In order to demonstrate the value of the reuse concept, a missile subsystem was built using the CAMP parts. Results indicate a significant increase in software productivity when developing systems using clean Ada, modern software engineering practices, robust software tools, and knowledgeable software engineers.

The required tasks associated with the CAMP project are described in three competitive contracts awarded to the McDonnell Douglas Missile Systems Company. CAMP-1 (September 1984 to September 1985) was a feasibility study which resulted in the design of 454 software parts and a supporting parts engineering system. CAMP-2 (September 1985 to May 1989) was an implementation and demonstration effort resulting in the initial distribution of CAMP software to over 250 government agencies and contractors. CAMP-3 (July 1988 to March 1991) is a refinement and technology transition program for the CAMP software and techniques. All CAMP products were developed in accordance with DOD STD 2167.

A domain analysis of missile flight software systems to identify commonality was performed during CAMP-1. This analysis included all categories of missiles (air-to-air, air-to-ground, and ground-to-air). Significant commonality was found. Parts requirements specifications and top level parts design were completed. In addition, a specification and architectural design was developed for the CAMP Ada Missile Parts Engineering Expert System (AMPEE) during this phase of the CAMP Project. The purpose of this system is to assist software engineers in locating, understanding, using, and managing CAMP parts.

The design, implementation, and testing of the AMPEE and associated parts were completed during CAMP-2. Flight software for an actual missile application in a real-time, processor-in-the-loop simulation was developed during CAMP-2. In addition, CAMP-2 tasks included the use of CAMP parts to develop a set of armronics benchmarks.

CAMP-3 is focusing on refining parts, transitioning the technology to new users, converting the AMPEE to Ada on a VAX, developing a training manual for Developing and Using Ada Parts in Real-Time Embedded Applications, and producing an executive overview video describing software reuse issues and the CAMP Program's approach to these issues. The video will examine the software crisis and the opportunity it has created for Ada and reusable software. The new AMPEE will contain numerous enhancements making it a suitable parts engineering system for a small company or for managing parts for a large system. Included in the enhanced AMPEE will be the development of a Meta-Constructor. The current AMPEE has 12 constructors used to develop special parts, such as autopilots and Kalman filters. The Meta-Constructor will be able to develop other constructors, reducing the intense effort required to constructors. The refined parts are scheduled for release in August 1989. The training manual for developing and using Ada parts and the catalog portion of the AMPEE will be released

The Data & Analysis Center for Software is operated for the Rome Air Development Center by Kaman Sciences Corporation

FIGURE 7.2 DACS BULLETIN

8.0 PRODUCTS AND SERVICES

A variety of traditional and new products and services were made available to the DACS users. In the CORE DACS area, they range from free answers to relatively minor questions on software engineering and technical areas to more formalized solutions to difficult problems. Many of the reports and traditional products and services are highlighted in other sections of this report.

DACS CORE PRODUCTS & SERVICES

- **TECHNICAL INQUIRIES**
- **BIBLIOGRAPHIC INQUIRIES**
- **DATABASE REPORTS/DATASETS**
- **STATE-OF-THE-ART-REPORTS**
- **CRITICAL REVIEWS/TECHNOLOGY ASSESSMENTS**
- **DATA ANALYSIS REPORTS**
- **MANUALS/HANDBOOKS/STANDARDS**
- **SOFTWARE TECHNOLOGY BRIEFINGS**
- **SELECTED PAPERS/PROCEEDINGS**
- **NEWSLETTERS/SPECIAL BULLETINS**
- **SPECIALIZED SOFTWARE DATA REPOSITORIES**
- **SIMULATION/MODEL DEVELOPMENT & EVALUATION**

Technical Inquiries were received in a variety of ways and processed daily by the members of the DACS Staff. Some inquiries were for general information on the DACS, products and services, or more specific in nature, such as questions on software engineering environments, etc. To satisfy these inquiries, the DACS response included forwarding one or more of the following:

- DACS Information Package
- Customized Bibliographic Search
- Document Distribution
- Database Subset Production
- Information Summary

- Information Analysis
- Referral to Other Sources

Bibliographic Inquiries were provided to individuals requesting searches of DACS data holdings or as a part of a technical area task. Routinely, a search strategy is developed and the results provided within two days of the request. The DACS maintains the capability to provide the results in hardcopy or softcopy form. Abstracts may cover the entire spectrum of our bibliographic database or they may be time or context limited. Almost 14,000 references are currently contained in the software engineering bibliographic database. Sometimes information was augmented by access to our other existing databases as well.

Database Reports/Datasets were produced upon request from our user community. Generally the information was pertinent to the software engineering lifecycle and incorporated information on cost, complexity, software problems, change data, and productivity and reliability factors. We also distributed information to potential users to assist them in determining their dataset needs.

State-of-the-Art Reviews are technical reports on software engineering technologies of major interest to our user community. They provide a consolidated look at specific areas of the technology in one document that describes the technology and include reference material useful for further study. The reports produced under this contract by members of the DACS staff and our subcontractors is discussed elsewhere in this report.

Critical Reviews/Technology Assessments take a more in-depth look at issues of software engineering and software technology. They provide some insight into the technology and assess the strengths and weaknesses of the technology and perhaps, specific implementations of that technology.

Data Analysis Reports consisting of empirical data maintained by the DACS in our databases and datasets were made available to our users in the form of analyzed data for comparison or validation activities.

Manuals/Handbooks/Standards The DACS distributed a variety of specialized products designed to bring procedural standardization to the software engineering community. We distributed DOD-STD-2167A, DOD-STD-2168, and a variety of other published standards to DACS users. We also prepared manuals and handbooks specific to technical area tasks to system and software owners and users.

Software Technology Briefings are provided to DACS users and potential users which describe the capabilities of the DACS staff and our subcontractors and well as general and specific descriptions of our products and services. We provided more in-depth looks at specific technologies in the field such as process automation using modern software tools and methods.

Selected Papers/Proceedings describing software engineering conferences or activities supported by the DACS or DACS staff members are periodically published to capture the activities of the conference, symposia, or meeting. Additionally, papers on aspects of software engineering were prepared for publication by members of the DACS staff for presentation at conferences or publication in appropriate journals.

Newsletters/Special Bulletins were published by the DACS throughout the year. Newsletters were published quarterly and bulletins are published eight times per year to coincide with the months a newsletter was not published. During this contract the newsletter has been substantially expanded and the quality, format, and content updated. The articles and information in the newsletter were geared to meet the needs and desires of our readers. The surveys we have conducted in the past have suggested the sort of mix of news, calendars and technical content that we provide. Numerous favorable comments have been received on the newsletter from our user community. The DACS bulletin has a much more limited distribution and provides information predominately to our local Rome Laboratory community. A popular area of coverage has been conferences on aspects of software technology and DACS activities in the field.

Specialized Software Data Repositories are maintained at the DACS. We have successfully arranged to house data from members of the American Institute for Aeronautics and Astronautics (AIAA) at the DACS. Several datasets have been received for test and evaluation purposes. We also arranged to receive Space Command Data for evaluation and analysis. As a part of a special study, we accepted the Robotics and Artificial Intelligence Database (RAID) and have integrated it into our holdings. It is anticipated that with the lack of special task funding, the DACS will augment RAID operation into a CORE activity.

Simulation/Model Development & Evaluation was periodically provided to our users by DACS staff members. The data is often reliability or cost data and models such as the Goel-Okumoto model are used for analysis and reporting purposes. As a part of a technical area task for the U.S. Army, a software metrics analysis tool is being prototyped for use by Army program managers. It will be distributed and supported at the DACS in future activities with the Army software engineering community and it may be augmented into the DoD community at a future date. We have also been involved in model/framework development and testing for aspects of software quality and software reuse component certification.

Our free informational guides to DACS Products and Services described our traditional state-of-the-art reports and critical reviews/technology assessments, and our database products. The following pages are a representation of our DACS Products & Services guide describing CORE support to the defense, academic and commercial DACS users.

Data & Analysis Center for Software 258 Genesee Street Utica NY 13502 (315) 734-3696

The Data and Analysis Center for Software (DACS) is a Department of Defense (DoD) Information Analysis Center sponsored by the Defense Technical Information Center (DTIC) and the Air Force's Rome Laboratory (RL). The DACS is operated by Kaman Sciences Corporation. The DACS serves as a centralized source for current, readily available data and information concerning software engineering and software technology.

Typical DACS products include subsets of the Software Life Cycle Empirical Database (SLED), data compendia, analysis reports, bibliographies, newsletters, and technical monographs. DACS services include accumulating, maintaining, and tailoring data subsets for software technology research; bibliographic searches of the Software Engineering Bibliographic Database (SEBD) that provide rapid access to documents, reports, and papers concerning software engineering and software technology; and special technical studies which include technology assessments, critical reviews, and state-of-the-art surveys.

DACS PUBLICATIONS AND DOCUMENTS

CURRENT AWARENESS PUBLICATIONS

- **DACS NEWSLETTER.** The DACS Newsletter is a quarterly publication (March, June, September, and December) that provides readers with a general awareness of significant developments, trends, and technical activities in the software field.

INFORMATION PACKAGES

- **ADA COMPILE SYSTEM (ACS) INFORMATION PACKAGE.** Package contains ordering information and a 'Statement of Terms and Conditions' for the Air Force's ACS software and documentation.
- **ADA COMPILER EVALUATION CAPABILITY (ACEC) INFORMATION PACKAGE.** Package contains ordering information and a 'Statement of Terms and Conditions' for the Ada Compiler Evaluation Capability (ACEC), software and documentation.
- **ADA FEATURES IDENTIFICATION SYSTEM (AFIS) INFORMATION PACKAGE.** Package contains ordering information and a 'Statement of Terms and Conditions' for the Ada Features Identification System (AFIS) software and documentation.
- **AIR FORCE ARMAMENT LABORATORY (AFATL) ADA COMPILER INFORMATION PACKAGE.** Package contains ordering information and a 'Statement of Terms and Conditions' for the Air Force's AFATL Ada Compiler and Interactive Debugger.
- **COMMON ADA MISSILE PACKAGES (CAMP) INFORMATION PACKAGE.** Package contains ordering information and a 'Statement of Terms and Conditions' for the CAMP products.
- **DACS INFORMATION PACKAGE.** A package of information describing the products and services offered by the DACS. The package contains sample DACS Newsletters, a *User's Guide to DACS Products and Services (DACSguide)*, a *User's Guide to Bibliographic Services (BIBGUIDE)*, and fliers on selected DACS products.
- **INTERSYSTEM ELECTROMAGNETIC COMPATIBILITY ANALYSIS PROGRAM (IEMCAP) INFORMATION PACKAGE.** Package contains ordering information and a 'Statement of Terms and Conditions' for IEMCAP and related programs.
- **ROBOTICS AND ARTIFICIAL INTELLIGENCE DATABASE (RAID) INFORMATION PACKAGE.** Package contains an overview of RAID, forms for adding your project, and instructions for accessing the database.
- **USER'S GUIDE TO DACS PRODUCTS AND SERVICES (DACSguide).** A descriptive brochure which provides an introduction to and ordering guidelines for DACS products and services.

DOCUMENTS

- **AIAA SOFTWARE TOOLS SURVEY.** Raw data compiled by the American Institute of Aeronautics & Astronautics (AIAA) Technical Committee on Computer Systems from a 1979 survey of aerospace-related industry, government, and university software tools in use or under development. 711 pages in 2 volumes, 1980. LIMITED STOCK.
- **ARTIFICIAL NEURAL NETWORKS TECHNOLOGY.** Describes what artificial neural networks are, how to use them, and where they are currently being applied. Seminal neural network architectures for prediction, classification, data association, data conceptualization, and data filtering are presented. 83 pages, August 20, 1992.
- **DACS GLOSSARY.** Contains definitions of terms from the software engineering literature. Prepared in conjunction with DACS participation on the IEEE Computer Society, Technical Committee on Software Engineering, Subcommittee on Software Engineering Standards, in writing the IEEE Standard Software

Engineering Terminology 137 pages. March 1981

- **A DESCRIPTIVE EVALUATION OF SOFTWARE SIZING MODELS.** Provides a comprehensive review and critique of software sizing models based on Source Lines of Code that are available to Air Force Cost Centers. The report illustrates general approaches to sizing, provides a consistent set of information for each automated model, identifies data required to apply the models, clarifies output results, and rates each model according to its relevance to intended users. 167 pages. September 1987
- **A DIRECTORY OF AIR FORCE ADA & JOVIAL SOFTWARE ENGINEERING TOOLS.** A listing of software engineering tools used by United States Air Force organizations and their contractors to develop and support software systems implemented in the Ada and Jovial programming languages. Based on a DACS database and a survey conducted in late 1986 and 1987. 257 pages. February 1988
- **DOD-STD-2167A, SOFTWARE DEVELOPMENT STANDARD (FEB 1988).** The joint military standard for Defense System Software Development and the supporting Data Item Descriptions (DIDS). Available either in hardcopy or on floppy disk. DOD-STD-2168, *Defense System Software Quality Program*; MIL-STD-483A, *Configuration Management Practices for Systems, Equipment, Munitions, and Computer Programs*; MIL-STD-490A, *Specification Practices*; and MIL-STD-1521B, *Technical Reviews and Audits for Systems, Equipment, and Computer Programs* are bundled with the hardcopy version. The floppy disks contain ASCII files for DOD-STD-2167A and associated DIDs.
- **EVALUATION OF ACEC AND PIWG BENCHMARK SUITES FOR ADA.** This report evaluates two benchmark suites for Ada. These suites were analyzed with respect to evaluating compilers for real-time embedded applications. 15 pages. April 1989.
- **EVALUATION OF UNIVERSITY OF MICHIGAN BENCHMARK SUITES FOR ADA.** This report evaluates the University of Michigan benchmark suite for Ada. The suite was analyzed with respect to evaluating compilers for real-time embedded applications. 13 pages. April 1989
- **GLOSSARY OF SOFTWARE QUALITY TERMS (DRAFT).** This draft glossary provides a single reference for definitions of terminology related to software quality. The terms are derived from efforts related to software quality sponsored by Rome Laboratory, the National Bureau of Standards, and the Air Force Operational Test and Evaluation Center. 18 pages. November 1985.
- **AN OVERVIEW OF OBJECT ORIENTED DESIGN.** This report summarizes the history of OOD, presents an OOD methodology, evaluates programming language support for OOD, and explores OOD's impact on software development. 83 pages. April 1991.
- **PIWG ADA PERFORMANCE BENCHMARKS: EXECUTION RESULTS.** This report documents the results from running the ACM SIGAda Performance Issues Working Group (PIWG) benchmarks on a Motorola 68020 computer with a MC 68881 math co-processor using the Verdix SUN/UNIX cross-compiler and a MicroVAX II using a self-hosted DDC-I compiler. 27 pages. April 1989.
- **PROCEDURES FOR COMPUTER-AIDED SOFTWARE ENGINEERING TOOL ASSESSMENT.** Describes procedures for life cycle assessment of CASE tools for tactical embedded systems. The procedures were developed by a DACS study. 66 pages. April 1989
- **QUANTITATIVE SOFTWARE MODELS.** Describes software lifecycle cost and productivity, software reliability, and software complexity models and methods. Includes matrices of data parameters for each method. (See also *Software Measurement Models*.) 159 pages. March 1979. LIMITED STOCK
- **REAL-TIME ADA PERFORMANCE BENCHMARKS: EXECUTION RESULTS.** This report documents the results from running the Real-time Ada Performance Benchmarks on a Intel 80386 computer using the Verdix DDC-I Ada compiler. 41 pages. April 1989.
- **A REVIEW OF SOFTWARE MAINTENANCE TECHNOLOGY.** Information on software maintenance tools and techniques compiled in 1979. This report contains matrices relating each tool or technique to various maintenance functions, an extensive bibliography, and a glossary of terms. 221 pages. February 1980. LIMITED STOCK
- **SOFTWARE ANALYSIS AND TEST TECHNOLOGIES.** Examines current software analysis and test technology and needs that should be filled by future technology. Analysis and testing includes all life cycle activities conducted to verify and validate the software product. 80 pages. February 1992.
- **SOFTWARE LIFE CYCLE TOOLS DIRECTORY.** Contains information about 412 software life cycle tools. Also contains a listing of tool acronyms by tool classification, implementation language, target computer, operating system, and features for easy cross referencing. 472 pages. March 1985
- **SOFTWARE MEASUREMENT MODELS.** A summary of software engineering measurement models. This report includes information on software reliability models, life cycle cost models, software sizing models and software complexity metric models. (Updates *Quantitative Software Models*.) 156 pages. July 1987
- **SOFTWARE PROTOTYPING AND REQUIREMENTS ENGINEERING.** Describes the motivation for software prototyping in general and specifically in requirements engineering. Summary analyses of software requirements and specification techniques and prototyping tools cover 20 techniques and tools. 162 pages. June 1992

- **SOFTWARE RELATED PROBLEMS AT THE CENTER FOR SOFTWARE ENGINEERING.** Assesses software related problems encountered in the day to day operations at the Center for Software Engineering (CSE) at CECOM, US Army, Ft. Monmouth, NY. Shows how CASE tools could help CSE personnel in addressing the identified problems. 17 pages. April 1989.
- **SOFTWARE REUSABILITY.** A summary of the state of the art in software reusability. This report describes important reusability projects around the world. Ada repositories in the U.S. and problem areas that hinder reusability from being common practice. 100 pages. August 1990.
- **STARS MEASUREMENT SURVEY SUMMARY.** A summary of the results of a survey to identify existing measurement databases, models, and software tools conducted from August 1985 to December 1985. 162 pages. May 1986.
- **A STATE OF THE ART REVIEW OF DISTRIBUTED DATABASE TECHNOLOGY.** Reviews the issues that arise with Distributed DBMSes, surveys commercially available Distributed DBMSes, and summarizes the state of the art. 40 pages. October 1992.

SOFTWARE ENGINEERING DATASETS

DATASETS

- **ARCHITECTURE RESEARCH FACILITY (ARF) ERROR DATASET.** Data describes 117 error reports, software characteristics data on 253 modules, and project aggregates for the ARF developed at the Naval Research Laboratory in the late 1970s. Available on an MS-DOS floppy disk or in hardcopy form.
- **DACS PRODUCTIVITY DATASET.** This dataset contains summary information from over 500 software projects, incorporating size data, error data, project duration, total effort, language data, and information on the usage of various software implementation technologies. (See *Software Data Collection and Analysis*.) Available on MS-DOS floppy disk.
- **NASA/AMES ERROR/FAULT DATASET.** Error/Fault data on 3,700 software problem reports collected on nine projects. Data was originally compiled by NASA/Ames Research Center in the late 1970s. Available on an ANSI standard 9 track tape or in hardcopy form.
- **NASA/SEL DATASET.** Data collected by the Software Engineering Laboratory (SEL), at NASA Goddard Flight Center, to measure the effectiveness of software development methodologies. The dataset contains over 45,000 records; the majority of the dataset is from component status reports and run analysis reports. The remainder of the dataset is project comment information, change reports, resource summary reports, and component summary reports. Last updated in December 1991. Available on 3 ANSI standard 9 track tapes.
- **PAVE PAWS OPERATIONS AND MAINTENANCE (O&M) DATASET.** O&M data collected on the PAVE Phased Array Warning Systems (PAWS) in the late 1970s and early 1980s. Available on an ANSI standard tape.
- **SOFTWARE RELIABILITY DATASET.** Failure data on 16 software systems collected during the phases of software test and operation during the 1970s. Suitable for validating software reliability models. (See *Software Reliability Data*.) Available on an MS-DOS floppy disk.
- **VALIDATION AND VERIFICATION (V&V) DATASET.** Data summarized from 1,500 anomaly reports on five V&V projects during the late 1970s. Available on an ANSI standard tape or as a hardcopy listing.

RELATED PRODUCTS

- **A COMPARISON OF DACS AND NASA/SEL SOFTWARE DEVELOPMENT DATA.** This report presents a statistical analysis of productivity data from the NASA/SEL and DACS Productivity Datasets. 27 pages. December 1982.
- **DACS DATA COMPENDIUM.** A description of software experience data available from the DACS. This document includes type of data, number of records of each type, record formats, and instructions for obtaining data. 66 pages. April 1992.
- **THE DACS SOFTWARE ENGINEERING DATA COLLECTION PACKAGE.** Produced by the DACS as part of an effort to organize the data items necessary to support analysis activities into a classification scheme and to promote standardized collection of software engineering data. The document contains an overview of the data collection process, a classification scheme for the different types of data which may be collected, examples for applying the package to specific types of analyses, data collection forms and instructions for completing the forms, a glossary of terms and data items, and an evaluation questionnaire. 87 pages. March 1984.
- **NASA/SEL DATA COLLECTION FORMS.** Forms used by the NASA Software Engineering Laboratory (SEL) to collect life cycle data on programs developed at the NASA Goddard Space Flight Center. The forms are used to collect data on general project information, changes, resources, components, and project personnel. 29 pages. February 1977.

- **NASA SEL DATA COMPENDIUM.** Specific information on 29 projects in the NASA SEL dataset with potential applications for the data. Contains 126 pages of text, charts, graphs, and forms. April 1981.
- **SOFTWARE DATA COLLECTION AND ANALYSIS (DRAFT).** An analysis of data from the DACS Productivity Dataset. This draft partial report contains statistics summarizing the distributions of key variables (size, effort, schedule, and fault density) and regressions. A special effort is made to display the effects of modern programming practices. September 1978.
- **SOFTWARE RELIABILITY DATA.** Written by Dr. John Musa of Bell Telephone Laboratories, this report summarizes the software reliability dataset and fits the Musa execution-time model to the data. 173 pages. January 1980.
- **STARS INTERIM SOFTWARE ENGINEERING DATA COLLECTION FORMS SET** A set of eight documents, Executive Overview and Final Report on the Interim Software Data Collection Forms Development and six Interim Software Data Collection Forms covering Resource Expenditure, Software Characteristics, Software Test Information, Software Problem/Change, Software Environment, and Software Evaluation. 327 pages. June 1985.

SOFTWARE ENGINEERING BIBLIOGRAPHIC AND PROJECTS DATABASE

The Software Engineering Bibliographic Database (SEBD) is collection of citations and abstracts for over 13,000 software engineering and software technology texts, technical reports, theses, journal articles, proceedings, standards, and other documents that are maintained in the DACS Software Engineering Library.

The Robotics and Artificial Intelligence Database (RAID) contains contact and project information on almost 2000 projects and over 900 organizations involved in Defense-sponsored research in robotics and AI.

CUSTOM SEARCHES

- **BIBLIOGRAPHIC SEARCH.** Custom search of the Software Engineering Bibliographic Database (SEBD). Use the BIBGUIDE to structure a search of the SEBD on one or more specific topics.
- **RAID SEARCH.** Custom electronic search of the Robotics and Artificial Intelligence Database (RAID). Use the RAID information package to structure a search of RAID. **Note: Export-Controlled Technical Data. Requires sponsor letter for nongovernment organizations.**
- **USER'S GUIDE TO BIBLIOGRAPHIC SERVICES (BIBGUIDE).** This document is a guide for ordering a DACS custom bibliographic search. The guide contains the DACS Software Engineering Thesaurus of keywords used for indexing and retrieving documents from the Software Engineering Bibliographic Database (SEBD).

BIBLIOGRAPHIES

- **THE DACS ANNOTATED BIBLIOGRAPHY.** A bibliography of software engineering literature contained in the DACS Software Engineering Bibliographic Database (SEBD). The Bibliography includes citations and abstracts of documents in the DACS Software Engineering Library, a keyword index built from the DACS Software Engineering Thesaurus, a subject index, an author index, and a Keyword-in-Context (KWIC) index. Volume I, (Accession Numbers 1-1624), published August 1980; Volume II, (Accession Numbers 1625-2214), published January 1982; Volume III, (Accession Numbers 2215-3013), published January 1983; Volume IV, (Accession Numbers 3014-4513), published June 1984; Volume V, (Accession Numbers 4514-5513), published December 1985; Volume VI, (Accession Numbers 5514-6513), published February 1988; Volume VII, (Accession Numbers 6514-7500), published April 1989; Volume VIII, (Accession Numbers 7501-9000), published December 1990.
- **THE DACS MEASUREMENT ANNOTATED BIBLIOGRAPHY.** A bibliography of 660 software measurement documents including texts, technical reports, theses, journal articles, conference proceedings, and standards. The topics covered in the bibliography include complexity measurement, cost estimation, life cycle costs, maintenance costs, productivity data, costing techniques, data analysis, software experience data, quality metrics, reliability measurement, reliability models, cost/productivity models, data collection, and data repositories. 263 pages. May 1986.
- **SOFTWARE ENGINEERING INSTITUTE'S TECHNICAL REPORTS.** The Software Engineering Institute (SEI) is a federally funded research and development center sponsored by the Department of Defense (DoD) under contract to Carnegie Mellon University. This bibliography contains citations of all SEI documents in the SEBD as of its production date. 41 pages. 1988.

PROCEEDINGS

- **KNOWLEDGE-BASED SOFTWARE ASSISTANT/ENVIRONMENT.** The Knowledge-Based Software Environment (KBSE), formerly the Knowledge-Based Software Assistant (KBSA), is a tool for software development and maintenance intended to support a transformational lifecycle paradigm. The KBSE uses Artificial Intelligence techniques and guidance to automatically transform formal requirements to designs and

code, with maintenance being performed on the formal requirements. Since 1986, Rome Laboratory has sponsored a conference to provide technical interchange between researchers and developers in the KBSE community. Annual proceedings for these conferences are available through the DACS for 1986 through 1992.

- **SOFTWARE QUALITY WORKSHOP.** For the last four years, Rome Laboratory has sponsored an annual workshop on software quality. Attendees and presenters have discussed all aspects of software quality and software quality measurement. Annual proceedings are available from the DACS for the first four annual workshops, from 1989 to 1992.

SOFTWARE ENGINEERING TOOLS

- **ADA COMPILATION SYSTEM (ACS).** The Air Force's 400,000-line fully self-compiled Ada compiler runs under the UTS operating system on IBM 370, 43XX, and 30XX computers. The UTS operating system is a Unix variant available from Amdahl either in "native mode" for Amdahl 580-series machines or on top of VM on IBM machines. This compiler was developed for Rome Laboratory by Intermetrics, Inc., and is distributed on two 9-track, 6250 bpi, Unix tar tapes. **Note: Export-Controlled Technical Data. Requires completed "Statement of Terms and Conditions" for distribution to any organizations other than those within the Air Force.**
- **ADA COMPILER EVALUATION CAPABILITY (ACEC).** The Ada Compiler Evaluation Capability (ACEC) was developed by Boeing Military Airplane Company for the Air Force Wright Aeronautical Laboratories. Its purpose is to provide the capability to determine the performance characteristics of Ada compilation systems. The ACEC products include the ACEC Software Product and three supporting documents: the *ACEC User's Guide*, the *ACEC Version Description Document (VDD)*, and the *ACEC Reader's Guide*. The ACEC Software Product consists of operational software and support software. The ACEC Software Product was developed for uniprocessor, uni-programming target systems and is distributed on one 9-track, 1600 bpi, VAX/VMS "backup" tape. **Requires completed "Statement of Terms and Conditions" for distribution to any organizations other than those within the Air Force.**
- **ADA FEATURES IDENTIFICATION SYSTEM (AFIS).** The Ada Features Identification System (AFIS) was developed by New York University for the ACVC Maintenance Organization (AMO) at Wright-Patterson Air Force Base. Its primary purpose is to aid the evaluation and maintenance of the Ada Compiler Validation Capability (ACVC), but it can be used to determine what features are present in any Ada program. The AFIS consists of the AFIS software product, the *AFIS User's Manual*, *An Introduction to the PAT Input Language*, and *the PAT Language Reference Manual*. AFIS is distributed either on three 9 track, 1600 bpi Unix tar tapes or on seven 9 track, 1600 bpi ANSI standard tapes. **Requires completed "Statement of Terms and Conditions" for distribution to any organizations other than those within the Air Force.**
- **AIR FORCE ARMAMENT LABORATORY (AFATL) ADA COMPILER AND ADA INTERACTIVE DEBUGGER.** The Air Force's AFATL compiler, written in Pascal, hosted on the CYBER 176, and targeted to the Z8002 microprocessor, was validated in October 1985. The debugger is written in Pascal and runs on the VAX 11/780. The AFATL Ada Compiler and Interactive Debugger are distributed on two 9-track ANSI standard tapes. **Note: Export-Controlled Technical Data. Requires completed "Statement of Terms and Conditions" for distribution to any organizations other than those within the Air Force.**
- **COMMON ADA MISSILE PACKAGES (CAMP).** The CAMP products include CAMP Parts, the CAMP Armonics Benchmarks, and the CAMP Parts Engineering System (PES). CAMP Parts are 444 reusable Ada components organized into 35 Top-Level Computer Software Components (TLCSCs) which contain 137,000 source lines of Ada code. The CAMP Armonics Benchmarks are used to evaluate Ada and processor implementations in the armonics domain. The tests establish the correctness of compiler implementations and measure performance in size and speed of generated code. The CAMP PES provides mechanisms for identifying and retrieving reusable software parts, adding new parts to the catalog, and data administrator functions. The PES runs on VAX VMS systems. CAMP Parts are distributed on two ANSI standard labeled 9-track 1600 bpi tapes. The Armonics Benchmarks are distributed on one 9-track 1600 bpi ANSI standard tape. The CAMP PES are distributed on three 9-track ANSI Standard tapes, two of which are 6250 bpi and the remainder is 1600 bpi. **Requires completed "Statement of Terms and Conditions" for distribution to any organizations other than those within the Air Force.**
- **GOEL-OKUMOTO SOFTWARE RELIABILITY MODEL.** An automated version of the Goel-Okumoto Nonhomogeneous Poisson Process Software Reliability Model which runs on an IBM-PC or compatible under MS-DOS 2.11 or higher. Features include the ability to find maximum likelihood estimators of the parameters defining the model by using either the Newton-Raphson or Muller's method; a goodness-of-fit test based on a Kolmogorov-Smirnov statistic; estimation of remaining faults, cumulative failures, and reliability; and estimation of the optimal release time based on certain cost criteria. This program is distributed on 5 1/4" MS-DOS floppy disk.
- **INTERSYSTEM ELECTROMAGNETIC COMPATIBILITY ANALYSIS PROGRAM (IEMCAP).** The DACS distributes certain Air Force Electromagnetic Analysis Codes of which the leading one is IEMCAP. **Requires completed "Statement of Terms and Conditions" for distribution to any organizations other than those within the Air Force.**

PRODUCTS & SERVICES ORDERING INFORMATION

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The DACS Full Service Participation Plan provides full access to DACS resources through payment of a single participation fee. Participants can request consultations, custom software tool searches, custom bibliographic searches, and DACS publications. Participants receive one copy of each publication when issued, discount privileges, access to DACS resources, and account maintenance. A DACS Full Service Participation Plan can be opened by depositing a minimum of \$500 (the maximum to be determined by the requester). The DACS will send the user a summary of plan purchases on a quarterly basis. Contact the DACS to establish a Full Service Participation Plan.

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As a DoD Information Analysis Center, the DACS is authorized to distribute unclassified export-controlled technical data, publications, and information. The DOD Directive 5230.25 (DD5230.25), "Withholding of Unclassified Technical Data from Public Disclosure," limits the distribution of unclassified export-controlled technical data to organizations certified as qualified contractors by the Defense Logistics Services Center (DLSC). Qualified contractors appear on the DLSC's *Qualified Contractor Access List (OCAL)*. Non-Government organizations can apply for DLSC certification by submitting a certification application (DD Form 2345, April 1986; Militarily Critical Technical Data Agreement) to the DLSC. (Note: Government activities do not have to submit to certification.)

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To obtain Air Force-owned products distributed by the DACS, a 'Statement of Terms and Conditions; Release of Air Force-Owned or Developed Computer Software' must be completed by all non-Air Force organizations. The Statement must be approved by the U.S. Air Force before any products can be shipped to an organization by the DACS.

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The United States Department of Defense only allows the export/transfer of products originated by the Data and Analysis Center for Software to foreign requesters on an international government to government basis. A written request should be sent to the appropriate foreign country's embassy identifying the DACS as the source of these technical reports. The embassy should then forward the request to:

U.S. Air Force Systems Command
HQ AFSC/XTID
Andrews Air Force Base, MD 20334-5000

They in turn will send the request to:

U.S. Air Force Rome Laboratory
RL/INF
Griffiss AFB, NY 13441-5700

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Except for DACS Full Service Participation Plan and DD Form 1155 orders, pre-payment of orders is required. Please make checks payable to 'Kaman Science Corporation.'

For additional information or ordering assistance contact the DACS at (315) 734-3696. Send completed order form and payment to the address on the next page.

PRODUCTS & SERVICES ORDER FORM

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INFORMATION PACKAGES			
ACS Information Package		Free	Forms
ACEC Information Package		Free	Forms
AFIS Information Package		Free	Forms
AFATL Ada Compiler Information Package		Free	Forms
CAMP Information Package		Free	Forms
DACS Information Package		Free	Package
IEMCAP Information Package		Free	Forms
RAID Information Package		Free	Forms
User's Guide to DACS Products & Services (DACSguide)		Free	Document
DOCUMENTS & RELATED PRODUCTS			
ATAA Software Tools Survey	\$50	(2) Documents	
Artificial Neural Networks Technology	\$30	Document	
DACS Glossary	\$30	Document	
A Descriptive Evaluation of Software Sizing Models	\$15	Document	
A Directory of Air Force Ada & Jovial Software Engineering Tools (Draft)	\$50	Document	
DOD-STD-2167A. Software Development Standard Documentation Set	\$50 \$25	(2) Documents (2) MS-DOS Floppy Diskettes	
Evaluation of ACEC and PIWG Benchmark Suites for Ada	\$10	Document	
Evaluation of University of Michigan Benchmark Suites for Ada	\$10	Document	
Glossary of Software Quality Terms (Draft)	Free	Document	
An Overview of Object Oriented Design	\$25	Document	
PIWG Ada Performance Benchmarks Execution Results	\$10	Document	
Procedures for CASE Tool Assessment	\$10	Document	
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Software Prototyping and Requirements Engineering	\$30	Document	
Software Related Problems at the Center for Software Engineering	\$10	Document	
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STARS Measurement Survey Summary	\$20	Document	
A State of the Art Review of Distributed Database Technology	\$30	Document	
DATASETS			
ARF Error Dataset	\$50 \$10	(1) MS-DOS Floppy Diskette Listing	
DACS Productivity Dataset	\$50	(1) MS-DOS Floppy Diskette	
NASA/AMES Error/Fault Dataset	\$50 \$30	(1) ANSI Standard Tape Listing	
NASA/SEL Dataset	\$150	(3) ANSI Standard Tapes	
PAVE PAWS O&M Dataset	\$50	(1) ANSI Standard Tape	
Software Reliability Dataset	\$50	(1) MS-DOS Floppy Diskette	
Verification and Validation Dataset	\$50 \$30	(1) ANSI Standard Tape Listing	

DATASET RELATED PRODUCTS

A Comparison of DACS and NASA/SEL Software Data	\$5	Document
DACS Data Compendium	Free	Document
The DACS Software Engineering Data Collection Package	\$10	Document
NASA/SEL Data Collection Forms	Free	Forms
NASA/SEL Data Compendium	\$10	Document
Software Data Collection and Analysis (Draft)	\$10	Document
Software Reliability Data	\$10	Document
STARS Interim Software Engineering Data Collection Forms Set	\$30	Document

BIBLIOGRAPHIC AND PROJECT DATA

	COST	FORMAT
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The DACS Measurement Annotated Bibliography	\$50	Document
Software Engineering Institute's Technical Reports	Free	Document
User's Guide to Bibliographic Services (BIBGUIDE)	Free	Document

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Volume IV	\$60	Document
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Volumes I, II, & III	\$125	(3) Documents
Volumes I through IV	\$180	(4) Documents
Volumes I through V	\$230	(5) Documents
Volumes I through VI	\$285	(6) Documents
Volumes I through VII	\$345	(7) Documents
Volumes I through VIII	\$405	(8) Documents

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KBSA 1989 Proceedings	\$50	Document
KBSA 1990 Proceedings	\$50	Document
KBSE 1991 Proceedings	\$75	Document
KBSE 1992 Proceedings	\$50	Document
Software Quality Workshop Proceedings 1989	\$65	Document
Software Quality Workshop Proceedings 1990	\$65	Document
Software Quality Workshop Proceedings 1991	\$50	Document
Software Quality Workshop Proceedings 1992	\$50	Document

SOFTWARE ENGINEERING TOOLS

Ada Compilation System (ACS)		
ACS Documentation Set	\$300	(16) Documents
ACS Source and Executable Software Package	\$125	(2) 6250 bpi Unix tar Tapes
Ada Compiler Evaluation Capability (ACEC)		
ACEC Software Product	\$50	(1) VMS Backup Tape
ACEC Documentation Set	\$50	(3) Documents
	\$50	(1) Tape

SOFTWARE ENGINEERING TOOLS (CONTINUED)		
Common Ada Missile Packages (CAMP)		
CAMP Parts	\$200	(2) ANSI Standard Tapes
CAMP Benchmarks	\$100	(1) ANSI Standard Tape
CAMP PES	\$300	(3) ANSI Standard Tapes
IEMCAP		
IEMCAP	\$100	MS-DOS Floppy Diskettes
	\$100	(1) Tape
IEMCAP IAP User Newsletter and Update Support	\$85	
IEMCAP User's Manual Volume I	\$20	Document
IEMCAP User's Manual Volume II	\$20	Document
Other Tools		
AFATL Ada Compiler and Ada Interactive Debugger	\$100	(2) ANSI Standard Tapes
Ada Features Identification System (AFIS)	\$300	(3) Unix tar Tapes
	\$500	(7) ANSI Standard Tapes
Goel-Okumoto Software Reliability Model	\$50	(1) MS-DOS Floppy Diskette
PARTICIPATION PLAN		
DACS Full Service Participation Plan (\$500 Minimum)	\$	

Check payable to "Kaman Sciences Corporation" is enclosed \$ _____

Apply this order to DACS Full Service Participation Plan #

DD Form 1155, Vendor identified as "Kaman Sciences Corporation, Data & Analysis Center for Software

The DACS uses United Parcel Service (UPS) for shipment of many products. Please indicate a street address as packages cannot be delivered to a PO Box by UPS. Send completed order form and **payment** to the following address:

**Data & Analysis Center for Software
PO Box 120
Utica, NY 13503
ATTN: Products/Services Order**

TITLE: () Mr. () Ms. () Dr. () Other:

NAME: _____

POSITION: *Marketing Manager*

ORGANIZATION

DIVISION:

ADDRESS: _____

CITY: _____ STATE: _____ ZIP CODE: _____

TELEPHONE: _____ DSN: _____

E-MAIL: _____ DATE: _____

8.1 Software Tools

We also made a number of tools available that were developed outside the DACS but made available to our users as a service to the defense software engineering community. These tools were provided on a cost reimbursement basis.

The DACS distributes certain software tools as a service to other Defense organizations. A software tool is any computer program or collection of software used in the development of other programs. Compilers, debuggers, test suites and benchmarks, libraries of reusable parts, and programs implementing models of software projects are all examples of software tools.

The DACS distributes the following tools:

- Ada Compilation System (ACS)
- Ada Compiler Evaluation Capability (ACEC)
- Ada Features Identification System (AFIS)
- Air Force Armament Laboratory (AFATL) Ada Compiler
- Common Ada Missile Packages (CAMP) Products
- A Computerized Implementation of the Goel-Okumoto Software Reliability Model
- The Software Engineering Cost Model (SECOMO)

CAMP, the AFATL Ada Compiler, AFIS, and ACS are all export controlled products.

SOFTWARE ENGINEERING COST MODEL

The Software Engineering Cost Model (SECOMO) is an interactive software cost estimation system that calculates the total staffing requirements for a Life Cycle Software Engineering (LCSE) Center of the Army Materiel Command (AMC). The technical direct-charged labor for developing and maintaining a system is based on the Constructive Cost Model (COCOMO). SECOMO also provides estimates of certain non-system specific personnel, the division of effort between the government and contractors, and the division of cost among different types of funding.

SECOMO outputs include effort in man-months, schedules in months, staffing estimates, and costs in dollars. These estimates are decomposed by system, life cycle phase, fiscal year, and so on. Graphical outputs are provided, where appropriate.

THE GOEL-OKUMOTO MODEL

The DACS developed a computerized implementation of the Goel-Okumoto Software Reliability Model for its own analysis purposes. The Goel-Okumoto model is one of many software reliability models developed over the past two decades by software engineering researchers. These models describe how a software program fails during either test or operations. The Goel-Okumoto model assumes software fails as a Non-homogeneous Poisson Process, one of the simpler stochastic processes with non-constant failure rates. A program's failure rate is assumed to be directly proportional to the number of bugs it contains. The model assumes that a single bug is removed immediately after every failure. Although DACS research has shown this assumption is not essential, Dr. Goel and Dr. Okumoto assumed that no errors are made while debugging.

Once the model has been fit to user provided data, the computerized program can produce various performance measures. These measures consist of the expected number of failures that will occur by any time, the remaining number of bugs in the software, reliability, and confidence bounds on all these measures. The program also provides a cost model for minimizing life cycle cost based on reliability considerations.

COMMON ADA MISSILE PACKAGES (CAMP)

The DACS distributes three Common Ada Missile Packages (CAMP) products developed by the McDonnell Douglas Astronautics Company under contract to the Air Force Armament Test Laboratory (Eglin AFB, FL). These products consist of the CAMP Parts, CAMP Armonics Benchmarks, and CAMP Parts Engineering System.

The CAMP Parts are 444 reusable Ada components organized into 35 Top-Level Computer Software Components (TLCSCs) which contain 137,000 source lines of Ada code (including comments, package specifications, package bodies, and test code). CAMP Parts are distributed on two ANSI standard labeled 9-track 1600 bpi tapes. The CAMP Armonics Benchmarks are used to evaluate Ada and processor implementations in the Armonics domain. The Benchmarks represent typical Armonics applications and include missile operational parts as well as support parts from the mathematical domain. The tests establish the correctness of compiler implementations and measure performance in size and speed of generated code. The documents the *CAMP Armonics Benchmarks Suite* and the *CAMP Armonics Benchmarks Suite Inventory* are shipped with the CAMP Armonics Benchmarks tape. The CAMP Parts Engineering System (PES), produced under the third phase of the CAMP product, is an improved version of the CAMP Ada Missile Parts Engineering Expert System (AMPEE). The PES catalog provides a means of identifying and retrieving reusable software parts. The PES allows new parts to be added to the catalog. The PES also provides for database administrator functions, and even a callable interface which supports the construction of new tools on top of the PES. Unlike AMPEE, the PES runs on commonly available platforms, namely VAX VMS systems. *The CAMP Parts Engineering System Catalog User's Guide* is shipped with the CAMP Parts Engineering System tapes.

ADA COMPILER EVALUATION CAPABILITY (ACEC)

The Ada Compiler Evaluation Capability (ACEC) was developed by Boeing Military Airplanes for the Air Force Wright Research and Development Center (WRDC). The DACS currently distributes release 3.0 of the ACEC. The ACEC provides the capability to determine the performance and usability characteristics of Ada compilation systems. The ACEC consists of the ACEC Software Product and three supporting documents: the *ACEC User's Guide*, the *ACEC Reader's Guide* and the *ACEC Version Description Document*.

The ACEC Software Product consists of performance tests, assessor tools and support software. The ACEC performance tests provide assistance in measuring execution time efficiency, code size efficiency, and compile time efficiency. The assessor tools provide assistance in evaluating symbolic debuggers, program library systems, and compiler diagnostics. The test suite does not include explicit tests for existence of language features.

The support software is a set of tools and procedures which assist in preparing and executing the test suite, in extracting data from the results of executing the test suite, and in analyzing the performance measurements obtained. The ACEC Software Product was developed for a variety of targets and is distributed on a nine track tape. The ACEC documentation is distributed in both hard and soft copy.

AFATL Ada Compiler

The Air Force Armament Laboratory (AFATL) compiler and debugger is a cross compiler hosted on a CDC CYBER 176. The compiler generates assembly language for a Zilog Z8002. The compiler was validated in October of 1985. The AFATL Ada Compiler is intended for laboratory use and should not be used in an operational environment unless further optimization is performed.

The compiler is composed of Pascal programs which support several phases of the compilation. Since the Z8002 has no operating system, a run-time support environment (RTE) is provided. The RTE consists of several Ada and Z8002 assembly language modules. Examples of some of the functions performed by the run-time system include run-time storage allocation, scheduling of tasks, run-time checks, and floating point arithmetic. The Ada Interactive Debugger (AID) was developed under contract to the Air Force Armament Laboratory (AFATL) as a tool for use with the AFATL Ada Compiler. The AID program is a menu driven, user friendly, source level debugger for Ada language applications software. It is implemented in Pascal and is hosted on the CYBER 176 computer system. The AID tool provides facilities to suspend, monitor, and trace the execution of Ada software by providing features such as breakpoint traps, data traces, and single-step execution. Since schedule constraints precluded extensive testing, the AID tool should not be viewed as production quality software.

ADA COMPILATION SYSTEM

The Air Force's Ada Integrated Environment (AIE) Ada Compilation System (ACS) was developed by Intermetrics, Incorporated under contract to Rome Laboratory.

The 400,000-line fully self-compiled Ada compiler runs under the UTS operating system on IBM 370, 43XX, 30XX computers, as well as plug-compatible machines such as those made by Amdahl. The UTS operating system is an UNIX variant and is available from Amdahl.

The compiler has been validated with the Ada Compiler Validation Capability (ACVC), version 1.8. It executes at 250 to 400 lines per minute on the IBM 4341 with an Ada to assembly language ratio of 1 to 4. The compiler contains a comprehensive global optimizer. Other compiler features include a partial implementation of chapter thirteen of the *Ada Language Reference Manual* (representation clauses and implementation-dependent features); extensive syntax error recovery; compilation statistics gathering; and generation of source, object, and symbol cross reference listing.

ADA FEATURES IDENTIFICATION SYSTEM

(AFIS)

The Air Force's Ada Features Identification System (AFIS) was developed by New York University for the ACVC Maintenance Organization (AMO) at Wright-Patterson AFB, OH. Its primary purpose is to aid in the evaluation and maintenance of the Ada Compiler Validation Capability (ACVC) but it can be used to determine what features are present in any Ada program. The AFIS consists of the AFIS software product, the *AFIS User's Manual*, *An Introduction to the PAT Input Language*, and the *PAT Language Reference Manual*.

AFIS was developed as an aid in the evaluation and maintenance of the ACVC test suite. The purpose of the system is to determine which of a set of specified Ada features are present in a given Ada program. The set of primary features is a pre-defined, fixed set of simple Ada language features derived primarily from terms used in the Ada Language Reference Manual, particularly the index and syntax summary. For the ACVC suite, the primary features corresponding to each test have been pre-computed and stored in the database. Other, non-ACVC Ada programs can be compiled and their sets of primary features added to the database; thereafter they may be queried just like the ACVC tests. The PAT allows the user to deal with more complex combinations of features. The user can specify a new and unique combination of features by writing a pattern in the PAT pattern language. The AFIS can be used to determine if a given program or any program in the database contains a user-specified pattern.

Two versions of AFIS are available from the DACS. The UNIX version is distributed on three, 9-track 1600 bpi UNIX tar tapes. The VMS version is distributed on seven ANSI standard 9-track 1600 bpi tapes.

9.0 PROMOTIONAL ACTIVITIES

There is no specific budget for promotion of the DACS. However, we did promote the DACS to members of the software engineering community through the publication and distribution of high quality textual materials such as the DACS Newsletter and a variety of technical reports described elsewhere in this report.

The DACS staff have also developed and maintain a variety of professional contacts in the software engineering, academic and defense communities which allow us to gain recognition for professional software engineering expertise among our peers.

We have also sought to join and participate with a variety of organizations nationally which provide a forum for us to participate in software engineering and technology efforts at a high level. Similarly we have contributed articles, time and information to those organizations to assist them to meet their national and international goals.

The DACS Director has contributed directly to the DoD Software Action Plan, the Defense Software Strategy Plan, the US Navy's Next Generation Computer Resources Program, the DoDs Militarily Critical Technology List, and to Institute of Electrical and Electronics Engineers (IEEE), Association for Computing Machinery (ACM) and International Standards Organization (ISO) standards and specifications efforts. Combined, these actions have a positive effect on the visibility and reputation of the DACS within the professional community.

The DACS staff has earned a reputation for understanding the software engineering and software technology needs of our users. Through our participation in and support of a variety of conferences, symposia and workshops, we have gained a substantial amount of information which we have used to enhance our internal capabilities and we have also made that information available to all of our users through our products and services.

10.0 TECHNICAL AREA TASKS

During this contract period, we performed a wide variety of special studies. Our DACS staff performed special studies and provided consulting services to members of the defense community, other government activities, industry and academia. The studies involved everything from conference support to verification and validation and included both traditional and new customers. Technical and support areas included the following:

- Acquisition Support
- Distributed/Parallel Processing
- Software Reuse/Reengineering
- Metrics/Measurement Assessments
- Analysis and Test Technologies
- Requirements Engineering
- Rapid Prototyping
- Language Studies/Tool Development
- Standards and Specifications
- Metrics Data Clearinghouse
- Software Quality
- Life Cycle Management
- Artificial Neural Networks
- Algorithm Development
- Software Image Processing
- Tools and Environments
- Cost and Reliability Modeling
- Risk Assessment
- Program Management
- Producibility Measures
- Process/Product Model Studies
- Conference Support
- Software Technology Training
- Software Signal Processing

The following paragraphs summarize the thirty three special studies conducted by the DACS staff for the defense software engineering community. Additional information may be available concerning a particular study by contacting the DACS Director.

10.1 Knowledge Based Systems Evaluation for Military Man-in-Space

U.S. Air Force Space Command (USAF SPACECOM/XPSS)

Task 9554F 2010

Air Force Space Command was reviewing concepts for supporting war fighting in near-real time with information from space-based sensors. Such a review included technology assessments of sensor, communications, and computer hardware, and assessments of systems technologies for fault tolerant networking, smart distributed computing, planning and scheduling aids, sensor fusion, and sensor data reduction. This effort was referred to as Advanced Data Acquisition, Processing and Transmission Center (ADAPT-C). The DACS has assisted Air Force Space Command by determining how artificial intelligence (AI) techniques could contribute to the ADAPT-C concept.

In the near term, the best way to demonstrate AI contributions was through the use of AI based simulations. The AI simulator not only provided a more user friendly simulation environment,

but it enabled the demonstration of AI methods in the target system being simulated. For example, AI based scheduling can be demonstrated by first simulating a specific satellite constellation; scheduling tasks may then be generated in the context of this simulation. An AI inference based scheduler can then be implemented to solve the scheduling problem. Finally, the AI scheduler's performance can be compared to a more traditional numerical methods scheduling approach.

"Active vision" ideas can be analyzed with the satellite simulation tool. For example, if one sensor spots an object and requests confirmation or increased resolution from a second sensor, the simulator can evaluate the best case, average case and worst case availability of the second sensor.

The simulation tool may also be valuable for evaluating the various land, air and space basing options for an ADAPT-C center. The relatively easy reconfiguration capabilities of an AI simulator can more easily accommodate this analysis than would be the case with traditional simulation tools.

10.2 Support Services for the 5th, 6th, and 7th Annual Rome Laboratory Knowledge-Based Software Assistant (KBSA) Conference

U. S. Air Force Rome Laboratory (USAF RL/C3C)

Task 9554F 2020

This study supported and tracked the progress of the development and activities surrounding Rome Laboratory's program for the development of a Knowledge-Based Software Assistant. The paradigm is based on formalization and machine capture of all software-related decisions and subsequently applying knowledge-based reasoning to assist with decision making.

The DACS provided complete conference support for Rome Laboratory from initial site survey to site selection, host service, and publication and distribution of the resulting Conference Proceedings.

The conferences were highly successful and attendance expanded considerably. The conference acceptance within the user community led partially to a decision to hold the conferences in more accessible areas.

10.3 Investigation of Automated Data Synthesis Techniques

U. S. Air Force Rome Laboratory (USAF RL/OCTS)

Task 9554F 2030

This DACS special task investigated new and novel approaches for software implementations and related algorithms for the processing of signals, information, and knowledge from multiple and diverse collection points. During the course of this investigation systems with an architecture of distributed data collection in which the data contained a wide variety of features/parameters arising from the same phenomena/event were considered. The algorithm resulting from this research provided for real-time update of the information/data synthesis process and related data processing to assure optimum system performance in a dynamic environment of changing

information acquisition. The algorithms developed under this effort were developed with provisions for defining data flow constraints between the data collection point and data synthesis point.

In the development of algorithms for such distributed information collection systems, we developed, with assistance from Dr. Parmod Varshney of Syracuse University, and made use of bounds on the following:

- Algorithm/system/software/hardware performance
- Algorithm/system/software/hardware design methodology
- Known entropy constraints and other relevant information theory concepts
- Investigation of the application of knowledge based techniques
- Investigation of the application of high level knowledge processing techniques such as blackboard systems
- Investigation of production systems which operate from a rule base for the control of data collection
- Investigation of distributed detection of information.

10.4 Software Quality Automated Method Validation: Setup & Support Task

U. S. Air Force Rome Laboratory (USAF RL/C3C)

Task 9554F 2040

In this DACS special task, the DACS, with support from a subcontractor, Software Productivity Solutions, defined and established a support function to form the basis of a larger effort titled "RADC Software Quality Initiative." This program combined the resources available from past efforts performed by Rome Laboratory, included efforts accomplished or sponsored by Rome Laboratory, and continued with the direction undertaken by Rome Laboratory. The common thread which bounds these efforts is research in the area of software quality.

The Laboratory Support Function exists to provide a mechanism to acquire a wide variety of technological support. It further serves to provide initial definition of a structure for the lab and its operation, as well as a physical location for the retention of operational hardware and data.

The Laboratory Support Function provided the management of overall technical support needed to oversee laboratory functions and to carry out specific subtasks. This function also included the preparation and development of materials and capabilities needed to support the sub task requirements for user training, installation and operation of software quality tools, expert consultation on the software quality tools and RSQF (Rome Laboratory Software Quality Framework), experiment design, and to analyze quality data and evaluate the RSQF and tools.

The preparation of sub task plans provided details concerning each demonstration/application or experiment that is to be performed. The subtasks consisted of activities that included installation and operation of the tools, user training, collecting, analyzing and interpreting quality data, and evaluating the technology. Specific requirements for each sub task was provided by Rome Laboratory as test projects become available.

Two categories of subtasks were anticipated. One required the installation and operation of the RSQF and tools at various contractor's plants. Contractor/support personnel were active participants in the demonstrations. With the assistance of the Laboratory Support Function contractor (and subcontractors as required), they operated the tools, collected and analyzed the data, etc. Roles, requirements, and duties were established for all participants.

The second type of sub task was intended to minimize project interference and required little involvement on the part of the software developer personnel. Copies of software products generated by the project were provided by the developer, but the experiment/demonstration sub task was performed by personnel available through the support function.

10.5 Software Engineering for Technical Data Package & Engineering Change Proposal System

U. S. Army Research and Development Engineering Center (ARDEC)/Battlefield Automation Technical Division (BATDD)

Task 9554F 2050

The main objective of this DACS special task was to provide software engineering expertise to the Technical Data Directorate at U.S. Army Research and Development Engineering Center (ARDEC), Dover, New Jersey, in their effort to develop a prototype system to handle the electronic routing of engineering drawings and related forms. This involved assisting in solving problems related to the loading of engineering drawings to an optical disk storage system, advice on the design of a configuration management system to handle engineering changes to documents being routed, and recommend enhancements and performance improvements to the system's user interface.

The front-end tools and languages currently being used in the development of the user interface to the Technical Data Package (TDP)/ Engineering Change Proposal (ECP) system with regard to ease of use, maintainability, response time and portability were reviewed. The TDP/ECP system was being developed using an older (1970's) forms and menus package for which the government owns the source code. This package lacked the features of more modern packages such as pop-up windows, sliding menus, multi-window view, etc. The TDP/ECP system software included 'C' interfaces to other Army systems and use Structure Query Language (SQL) for database queries.

The engineering drawings being scanned with the current technology had several problems which were analyzed. For example, older engineering drawings contained lines drawn in black pen, lead pencil, colored pens and pencils, etc. and were frequently stained. The various intensities, line thicknesses and shades of gray made the scanning of these documents a difficult process; settings at either end of the scale caused markings at the other end to disappear or bleed. New commercially available state-of-the-art scanning hardware/software, such as high resolution

flatbed color scanners and aperture card readers, which could improve the customer's scanning rate of success were examined.

10.6 Develop Methodology and Evaluation Criteria for Conversion of Technical Data Package and Engineering Change Proposal System

U. S. Army Research and Development Engineering Center (ARDEC/BATDD)

Task 9554F 2060

This DACS special task was concerned with identifying the best commercially available front-end development tool to be used in the Technical Data Package (TDP) conversion. The U.S. Army Research and Development Engineering Center (ARDEC) located at Dover, New Jersey developed a Distributed TDP/Engineering Change Proposal (ECP) Tracking and Reporting System which satisfied the following main objectives: to improve response time and quality, provide absolute, rapid accountability, management oversight and notifications of pending TDPs and; to provide for paperless routing of documents through the ECP process, to include drawings, handwritten and/or electronic documents in order to shorten the process.

The current TDP/ECP system software was developed using an older (1970's) forms and menus package that was difficult to maintain and required a long learning curve for programmers. To make the system more maintainable and portable to other hardware, operating systems and databases, the TDP/ECP software was converted to use a modern interactive and easy to understand development system that doesn't require a high degree of traditional programming and that is easily ported across multi-vendor hardware and software environments.

Several leading commercially available front-end menus and forms products were reviewed for functionality and compatibility with the existing hardware and database systems. From the field of available packages, three candidates were chosen for analysis of performance factors defined specifically for the TDP/ECP application and its user community.

User acceptance of an automated forms system is determined by factors such as system availability, dependability, responsiveness, "friendliness", in addition to the other system performance factors such as maintainability, functionality, portability, transaction rates, network connectivity, database compatibility, etc. An evaluation suite for the TDP/ECP front-end software was evaluated, as well as the development of prototypes using each of the three candidate front-end tools against this suite.

10.7 Man-Machine Interface Experiment

U. S. Air Force Rome Laboratory (USAF RL/OCTM)

Task 9554F 2070

This DACS special task examined and assessed the Rome Laboratory Software Quality Framework (RSQF) in the course of upgrading a currently existing multichannel signal processing software system. The new version of the signal processing software interfaced with the user by means of the User Front-end Interface (UFI) as a component of the Multisensor Algorithm Experiment (MAX).

Rome Laboratory/C3C has sponsored research over the last decade that has resulted in a collection of software metrics intended to assess such management-oriented quality factors as reusability. Controlled experiments focusing on narrow aspects of the Software Quality Metrics framework were performed, creating a foundation for validation. Two software systems for Rome Laboratory/OCT were developed, which provided a platform for assessing the metrics under one quality factor, namely reusability. These software systems can also be used as a mechanism for developing a model for estimating the cost of applying the framework.

The existing multichannel signal processing software, developed for Rome Laboratory/OCTM, synthesizes and analyzes multichannel signals. The signals consist of sums of auto-regressive processes and white noise, while the analysis consists mostly of time domain methods. The functionality of this system meets its primary requirement, exploring the false alarm rate and probability of detection of a new signal detection algorithm. The other system, the Multisensor Algorithm Experiment (MAX) system, was developed for Rome Laboratory/OCTS. A sophisticated man-machine interface for this system, the User Front-end Interface (UFI) was also developed.

The purpose of the modification effort was to create a new version of the multichannel signal processing software under the UFI. The new system was developed by reusing as much code as possible from the currently existing system. During the modification effort, data was collected to perform a quantitative assessment of the capabilities of the Rome Laboratory Software Quality Metrics to measure reusability.

10.8 Development of Standards and Configuration Management for Army Open Systems Architecture

U.S. Army ARDEC/BATDD

Task 9554F 2080

This DACS special task aided in the review and extension of Army MIS standards as they apply to the Technical Data Package (TDP)/Engineering Change Proposal (ECP) operating environment. Another function of this DACS special task focused on the development, implementation and evaluation of a configuration management plan for the TDP/ECP operating environment.

The new Army systems being developed for the 1990's and beyond will encompass the concept of open systems architecture. Where the existing Army standards address standalone hosts with resident applications and databases, the new standards need to address distributed applications and databases running in a network environment on heterogeneous machines. Such standards will address concepts such as the following: communication protocols for both local area and wide area networks (TCP/IP, X.25, SNA, etc.) and network management; database query languages (SQL, 4GL, etc.); operating system interfaces (POSIX, X/OPEN, AT&T System V Release 4, BSD 4.3, OSF1, etc.); terminal interfaces (VT100, 3270, PCs running emulation software, etc.) and; page description languages (POSTSCRIPT, HPGL, EPSON, DIABLO, etc.).

The new Army systems incorporate not only the new hardware and software, but also make use of the existing hardware and some software systems. This "incorporation" includes the concept of interchangeable parts where the application behaves consistently across hardware and database platforms.

The Technical Data Package/Engineering Change Proposal (TDP/ECP) system is moving to an open systems architecture. The DACS special task was designed to run the application software on a variety of host machines (SUN, AMDAHL, UNISYS, DEC), perhaps concurrently, and to interface with several databases (SYBASE, ORACLE, INFORMIX, PROGRESS). Since this system is the first of its kind being developed for distribution to heterogeneous environments, a configuration management plan was developed that regulates not only the application software but also the environments in which it operates.

10.9 GTD/Scatter Code Integration and Assessment Program

U. S. Air Force Rome Laboratory (USAF RL/RBCT)

Task 9554F 2090

A variety of computer programs exist in many application areas. Such programs will not remain in use long if they are not integrated with new, more efficient algorithms as they are developed. Likewise, these application systems need to be transitioned to take advantage of new, more powerful architectures as they become available. Such enhancements and modifications should retain the advantages of the original design, while making use of improvements in software engineering practices made since the original implementations. This DACS special task examined these issues in the context of software systems for electromagnetic effects, especially the General Electromagnetic Model for the Analysis of Complex Systems (GEMACS); integrating new algorithms into these software systems and; modifying them to run on advanced parallel architectures.

Rome Laboratory/RBCT has sponsored the development of a variety of software systems for investigating electromagnetic effects such as High-Power Microwaves (HPM), Electromagnetic Interference (EMI), Electromagnetic Pulse (EMP), lightning, Electronic Countermeasures (ECM), sidelobe susceptibility/vulnerability jamming, and ultra-wideband (UWB) effects. One of the most powerful and flexible of these computer programs is the General Electromagnetic Model for the Analysis of Complex Systems (GEMACS). The problems attacked by GEMACS were of particular concern among Atmospheric Defense Initiative (ADI) antennas and platforms. To keep GEMACS in continual use, however, recent advances in engineering understanding of electromagnetic effects, numerical algorithms, and computer architectures had to be integrated with GEMACS to produce a more powerful software system.

The results of this study were documented in a technical report discussing the problems raised by such enhancements and integration, and recommending software engineering programming practices and coding standards for dealing with these problems.

10.10 Investigation of the Quality of Signal Processing Software

U. S. Air Force Rome Laboratory (USAF RL/OCTS)

Task 9554F 2100

Rome Laboratory/C3C had developed a methodology for assessing the quality of software, the Rome Laboratory Software Quality Framework (RSQF), but had not yet developed extensive experience with it in any application area. Rome Laboratory/OC developed software for signal

processing systems and algorithms, thus providing a candidate application area for validating the RSQF. This DACS special task applied the RSQF to a signal processing system and algorithms developed by Rome Laboratory/OC. The Quality Evaluation System (QUES), a software measurement tool developed by Rome Laboratory/COEE, was used as an aid in applying the RSQF.

The main objective was to develop a few signal processing algorithms to provide a test bed for the RSQF and QUES. The algorithms, developed by Syracuse University Professor Dr. Hong Wang under subcontract to the DACS, were developed to address the problems of statistically characterizing a radar signal environment, developing optimal adaptive space-time processing methods and optimal local detectors. These algorithms explored the implications of various system architectures and the environment in which a signal processing system must operate.

10.11 Ada 9X Implementation Analysis Support

U.S. Air Force Systems Command (SC/AFAL)

Task 9554F 2120

The Department of Defense mandated the use of the Ada programming language on all mission critical systems. Proper use of Ada requires the application of certain important software engineering concepts. Hence, Ada is a major vehicle for the transition of software engineering techniques within the defense community.

The American National Standards Institute (ANSI) and the Department of Defense procedures require that action be taken periodically to reaffirm, revise, or withdraw the Ada language standard, ANSI/MIL-STD-1815A. The Ada Joint Program Office (AJPO) had determined that a revision was necessary. On 25 October 1988, the Director of the AJPO announced the initiation of the revision process, referred to as the Ada 9X Project.

The overall goal of this DACS special task was to revise ANSI/MIL-STD-1815A to reflect current essential requirements with minimum negative impact and maximum positive impact to the Ada community. The Ada 9X Process was a revision and not a redesign of the language and should be viewed as a natural part of the language maturation process.

Requirements for the Ada 9X revision process were developed by the Ada 9X Project Requirements Team from New York University. These requirements were based on revision requests from the Ada community, workshop/public meeting results, military service Ada waivers, Ada 9X Project focused study results, and public comments.

The Mapping/Revision Team mapped the requirements developed by the Requirements Team into recommended solutions, and revised ANSI-MIL-STD-1815A based on these solutions.

10.12 Prototype Software Metrics Analysis & Project Management Tool Investigation

U. S. ARMY Operational Test & Evaluation Command

Task 9554F 2130

The purpose of this DACS special task was to develop a computer-based prototype tool for assessing and analyzing software metrics in support of the U.S. Army Operational Test & Evaluation Command (OTEC) mission. Tasks were performed by members of the DACS staff and a DACS subcontractor, Dr. Amrit Goel of Computer Software Modeling Associates. The analyses are being performed on Army-wide metrics databases to be generated for various Army Information Systems (AIS) and Material Systems Computer Resource (MSCR) projects. This analysis is important to assess the progress of a software project and to predict via analytical models, important quantities such as software reliability and operational test readiness. Analyses are also be performed to support the management of future projects.

Several subtasks were pursued during the development and implementation of the aforementioned prototype tool. The first task was the development of a database specification and schema for an Army-wide software metrics database which allowed multiple users to store, maintain and retrieve metrics associated with various projects. The second task was the incorporation of validation criteria to make the metrics database credible. For example, two different metrics for complexity should not provide contradictory or inconsistent information about the software project to a user for the metrics database. This task identified functionality needed to provide automated support for metric validation, assessment and correlation.

The third task dealt with identifying, early in the life cycle, those components of an on-going project in the software metrics database which may need special attention. This information may be sought from an analysis of the requirements and design documents of the project. Previous experience in dealing with similar components, documented in a metrics database, was helpful in the process. This task developed a scheme for querying the metrics database to produce integrated metric sets related to target attributes and/or goals.

The fourth task focused on the development of an analytical framework for identifying problem areas and tracking trend indicators for selected metrics. The fifth task identified salient features of an on-going project which may be used to query the metrics database for similar project histories. When appropriate features are identified, much can be learned from previous projects to predict and manage new ones.

The previous tasks identified the required functionality of a prototype software metrics analysis and project management tool. In addition, they developed methods for providing that functionality. The sixth task implemented those methods in a running prototype, which may be the basis for developing a production quality tool at a later date. The seventh task explored the similarities and differences between Army and Air Force metric collections.

10.13 Evaluate Conversion of the ARDEC AMAS

U.S. Army ARDEC/BATDD

Task 9554F 2140

The U.S. Army Research and Development Engineering Center (ARDEC) located at Dover, New Jersey currently is operating an office automation system called the Automated Materiel Acquisition System (AMAS), which provides ARDEC personnel with an electronic means of submitting and tracking requests for supplies and non expendable materiel (under \$25,000.00). AMAS was developed with the objectives of reducing the administrative time involved in the requisitioning process, reducing errors in the process, and providing requisitioners with an automated tracking mechanism.

The current AMAS has serious portability and maintainability problems. Porting the system to another flavor of Unix, or to another hardware platform, has historically taken from six to twelve months. The system is tightly bound to proprietary/non commercial user interface software developed in the 1970's, and has proven extremely difficult to debug and enhance.

The Technical Data Package (TDP)/Engineering Change Proposal (ECP) system has been prototyped, using a database driven user interface. The conversion approach, using tools developed, resulted in substantial labor savings and error reduction.

This DACS special task met the following objectives: generalize and extend the tools developed under previous studies dealing with the TDP/ECP system; evaluate these tools in the context of converting the AMAS system and; develop a functioning AMAS prototype that is more maintainable and portable than the existing system.

10.14 Operation & Maintenance of the Robotics & AI Database (RAID)

U.S. Navy Naval Oceans Systems Center

Task 9554F 2150

The RAID database was designed as a information support system for program managers and as a technical knowledge base for robotics and AI researchers. Operation and maintenance of this database was taken over by the DACS from Computer Sciences Corporation with their transition support, as a special task through the Naval Ocean Systems Center and funded jointly by the services. In the future it may become a CORE activity.

It contains an electronically accessible collection of project abstracts. The information stored in RAID is gathered from and verified by a variety of sources. The topics included in the database are retrievable by keywords in a broad range of technical fields and by system applications of interest. PROJECT INFORMATION - includes a description of research (both an abstract and a classification), responsible DoD organization, performing organization, names and phone numbers of the points-of-contact, and funding information. CONTACTS INFORMATION - includes the address, phone number, interest areas, and electronic mail address of individuals and organizations involved in robotics and AI research and development. Database users can select and combine information to meet their needs by direct, on-line access or by requesting the RAID staff to tailor report formats to meet individual user requirements.

The information contained in RAID is considered Military Critical Technology (MCT). There are currently more than 2068 projects and 3143 contacts records in RAID affiliated with 840 valid organization records. RAID offers services and products to provide the user with an increased information base and increased on-line capabilities. The following services and products are currently provided at no cost to users:

- On-line RAID Access
- IAC Staff Search and Report Generation
- Executive Summary Report
- Related Projects Executive Summary Report
- Electronic Communication
- Events Calendar
- Conference Summaries
- Mailing Address Data Files

10.15 Signal Processing for Remotely Located Sensors

U.S. Air Force (USAF RL/OCTS)

Task 9554F 2160

This DACS special task, conducted with subcontractor support from Syracuse University Professor, Dr. Parmod Varshney, investigated distributed systems data synthesis and signal management techniques. The main objective was the derivation and development of novel software approaches for multi-sensor signal processing and data fusion applications. Problems in this area involve the merging of diverse information from different sources (i.e. RF, IR) into coherent representations of the processed scene. These representations included the detection, estimation, classification of the processed scene, and the control of the multi-function signal/information processing systems. Research involved in this study is geared towards providing alternative means to using classical, Bayesian, or Minimax decision approaches previously applied to this problem. The methods used made use of heuristic as well as analytical means for the derivation, development and formulation of these algorithms.

This project improved software practices for multi-sensor signal processing and data fusion by developing new methodologies and applying them to application areas of great interest to the DoD community.

10.16 Independent Verification & Validation Support for the Range Control System

U.S. Air Force (USAF RL/OCDS)

Task 9554F 2170

The purpose of this DACS special task was to provide software engineering support to Rome Laboratory(RL)/OCDS. RL/OCDS was acting as system integrator and software acquisition manager for the Range Control System (RCS), a large computer system for tracking planes and ships in the Gulf of Mexico during operation of the Air Force practice range. The DACS and subcontractor Mr. Dana Harris of Presearch, Inc., supported RL/OCDS through generation and review of DOD-STD-2167A documentation, Ada code review, the collection and analysis of software quality metrics and management indicators, and Independent Validation and Verification (IV&V) for document reviews, design reviews, and Software Quality Assurance (SQA).

RL/OCDS had mandated the use of Ada, DOD-STD-2167A, management indicators of problem areas, and quantitative measures of software quality based on the Rome Laboratory Software Quality Factor Framework (RSQF) in the development of RCS software.

There were several goals for this study. The first goal was to provide technical advice relevant to RCS system integration, software acquisition, and development quality to RL/OCDS. In addition, a software quality measurement program was developed to collect data needed for the Air Force Management Indicators and for the quality factors which may be addressed such as Reliability, Maintainability, Correctness, and Flexibility. Third, any documentation produced by the RCS software development, including DOD-STD-2167A documents, was reviewed. Next, configuration management as defined by DOD-STD-2167A was monitored and the results reported to RL/OCDS. Lastly, an independent assessment of the Ada compiler and other elements of the RCS software within the development environment was to be performed.

Due to loss of funding this project was terminated prior to its conclusion.

10.17 Battlefield Damage Assessment Capabilities and Evaluation

U.S. Army Missile Command (USA (AMSMI-SW))

Task 9554F 2180

The purpose of this DACS special task was to evaluate the applicability of transitioning a new advanced software technology, known as Virtual Interactive Prototyping (VIP), to the DoD user community. This was accomplished by developing a test case VIP of the battlefield damage assessment (BDA) mission for indirect fire support smart weapon systems and evaluating the "applications development process" and "software life-cycle management" implications.

There existed several objectives in this program. The primary objective was to determine the applicability of VIP to the weapons development community. Secondary objectives included: the definition of a method for interactive simulation design using knowledge based environments (integration of object-oriented programming and expert systems into a single simulation system), the transition of this technology to the weapons development community and an evaluation of

the spiral model of development for rapid prototyping as a model of the VIP development process.

The Army Materiel Command Smart Weapons Management Office (AMC-SWMO) served as the focal point for the oversight of smart weapons programs. These responsibilities included providing planning, technical evaluations, recommendations, coordination and in some cases, execution of smart weapon program activities. This included the definition of the BDA technical performance requirements.

The BDA mission in today's battlefield is a complex operation which involves multiple command, control, communication and intelligence (C3I) systems. A VIP of the decide, detect and deliver Smart Weapons process to include the damage assessment process will require a technical understanding of C3CI, weapon effectiveness, target vulnerability, kill assessment, sensor resolution and forward observer operations and capabilities. The VIP was developed from the concept of operations definition and software requirements analysis of the BDA process. The concept of operations was derived from a thorough requirements analysis which identified all systems and subsystems involved in BDA, the specific mission of each system or subsystem, performance measurements for each system or subsystem and system requirements. The concept of operation formulated from the requirements analysis was from the initial prototype, from which a detailed prototype design will be developed.

10.18 Design Rapid Prototype Approach to Software Simulation for ADAPT-C Ground Test

U.S. Air Force Space Command (USAF AFCS/SSD)

Task 9554F 2190

The main objective of this DACS special task was to support a future concept evaluation effort for Air Force Space Command. The Air Force was planning a large software simulation ground test for a future space system. This evaluation required rapid multiple reconfigurations of the simulator to evaluate design options for an extremely high bandwidth system of complex satellite constellations.

This DACS project provided technical guidance on the use of rapid prototyping environments for the planning, design, coding, and evaluation phases of the required software simulation. Emphasis was on object oriented programming approaches and on parallel computer architectures. Object oriented programming should facilitate rapid reconfiguration of the simulator. Parallel processing may be required to simulate the extremely high bandwidth of each satellite while also simulating a large constellation of satellites. Such capabilities are at the state-of-the-art in computer simulation technology.

This project was related to an early DACS project for Air Force Space Command, titled "Knowledge Based Systems Evaluation for Military Man in Space". The first effort investigated the possible applications of artificial intelligence(AI) techniques to a space-based, possibly manned, surveillance system. The final report recommended that AI methods be utilized in three areas: knowledge based simulation; inference based planning, scheduling, and command and control; and knowledge based sensor cueing, perception, and fusion.

This project was most closely related to the first recommendation, but it may also impact the second. A software system that uses rapid prototyping for quick evaluations of alternative concepts, during the design and development phases of a complex space system, could also be used during the operational phase to support planning, scheduling, and command and control functions. In fact, the knowledge based simulator might become the core of the command and control component of the operational space system. This project did not build a simulation, but did recommend software and compatible hardware facilities for a highly flexible knowledge based simulation. While not building a complete simulation some simple components of a simulation may be implemented and were included in the report as examples.

10.19 Evaluate the Maintainability of the TDP Tracking System

U.S. Army ARDEC BATDD

Task 9554F 2200

The US Army Research and Development Engineering Center (ARDEC) located at Dover, New Jersey is currently undertaking the development of a Distributed Technical Data Package (TDP) & Engineering Change Proposal (ECP) Tracking & Reporting System for eventual use with the major commands of the Army Munitions and Chemical Command (AMCCOM). The following are the main objectives of the system:

- To improve TDP processing time and data quality, promote immediate accountability of work, and enforce management oversight and notifications of pending technical data packages.
- To upgrade operational capabilities and provide an environment of paperless document routing through the ECP process, including drawings, handwritten data, and/or electronic forms in order to shorten the time to process a TDP.

Under a previous DACS Special Study, Kaman Sciences used the JYACC Application Manager (JAM) to produce the prototype TDP Tracker. We found that we could produce the application faster and more uniformly under the JAM environment than we could with a traditional, third generation language approach. The prototype has been installed and tested by AMCCOM at several locations.

Maintainability is a quality measure of the ease with which software can be understood, corrected, adapted, and/or enhanced. We considered maintainability during prototype development: we noted areas of future enhancement and potential revision, discussed portability issues, and considered possible system interfaces. This task evaluated how quickly and easily modifications can be made to the prototype's software and established mechanisms to improve maintenance response time where required. The results of this task were be an input to the task of building the full TDP/ECP Tracker System.

10.20 Software Quality Lab Support Task

U.S. Air Force Rome Laboratory (USAF RL/C3CB)

Task 9554F 5000

This special study, consisting of a variety of subs tasks, paralleled the activities and charter of the DACS and continued to define and establish support for Rome Laboratory's Software Quality Initiative. This task provides follow-on support to Rome Laboratory from an earlier task , numbered 9554F 2040.

The Laboratory Support Function provided a mechanism to acquire varied technical support and maintain operational hardware and data. Also included was the preparation of materials and capabilities needed to support the subtask requirements for training, installation and operation of the following tools:

- Quality Evaluation System (QUES)
- Rome Laboratory Software Quality Framework (RSQF)

Also included in this technical area task was the design of experiments, and quality data analysis.

Substantial support was provided to the DACS through subcontractors Mr. Ed Comer of Software Productivity Solution, Inc., and Mr. Gerald Murine of Metriques, Inc.

10.21 Enhancement of Multichannel Signal Processing Simulation System

U.S. Air Force Rome Laboratory (USAF RL/OCTM)

Task 9554F 2300

This special study was related to a previous task conducted by the DACS for Rome Laboratory. The study produced a Multichannel Signal Processing Simulation System (MSPSS) that supported the investigation of a signal detection algorithm. The study served to demonstrate the integration and extension of the User Front-end Interface (UFI) and Graphics User Interface (GUI) and fourth generation automatic programming system, in an application other than that for which it was originally developed. Since the application software for the new MSPSS was largely developed from components of a previous system, the previous study also served to investigate reuse, particularly its measurement with the Rome Laboratory Software Quality Framework (RSQF).

The MSPSS was implemented under a modern GUI using windows, menus, and a pointing device. The back end generates FORTRAN programs out of existing components specific to the user's description of his analysis. Thus the MSPSS was also an automatic programming system.

This task documented the MSPSS and otherwise increases its usability. Since the system used a fairly self-documenting GUI, this documentation concentrated on precisely describing the algorithms provided by the system.

This task was a direct outgrowth of a formal experiment which investigated software quality metrics.

10.22 Prototype Software Metrics Analysis, Project Management, and Risk Analysis - Phase 2

U.S. Army Operational Test & Evaluation Command

Task 9554F 2400

This special study continued the work on a prototype of an automated tool to support the assessment of operational effectiveness and suitability of software early in the continuous evaluation process. This task defined additional tasks required to expand the prototype tool to a system for Measurement-Based Software Risk Management (MBSRM).

The following tasks, supported by DACS subcontractor, Dr. Amrit Goel of Computer Software Modeling Associates, Inc., were accomplished for this special study:

- Developed a top-level design of the MBSRM to provide “super metrics” for risk assessment
- Provided enhanced capability to define the interrelationships of data elements and to perform statistical analysis of metric data
- Rule-based schemes were examined to establish overall procedures for the application of measurements to drive software risk management
- Developed “information hiding” in the tool - the concept that the user will obtain added output without having to be an expert in software engineering, software reliability and statistics, because of the implementation of “super metrics.”

This special study will aid the US Army Operational Test and Evaluation Command to implement Army mandated metrics collection and analysis programs.

10.23 Advanced Distributed Data Processing Techniques for Heterogeneous Network Systems

U.S. Army ARDEC/BATDD

Task 9554T 2500

In an effort to develop systems that operate in an “open systems” environment, the US Army Research, Development, and Engineering Center’s Battlefield Automation and Technical Data Directorate (BATDD) has sponsored, through the DACS, software Engineering studies into the requirements of their systems. A product of these studies has been the development of prototyping tools to be used in generating advanced office automation systems which handle electronic forms generation and routing algorithms for networked systems operating across heterogeneous hardware and software platforms. It is planned that the technology developed in these studies will be transitioned to solve other office automation and management requirements within the Army’s Armament, Munitions, and Chemical Command (AMCCOM). The

technology developed may also be transferred to generic software engineering system development activities pursued by the DACS.

The scope of this special study was to investigate, evaluate, report and prototype advanced distributed data processing techniques, tools, and methods for networked systems with the objective of improving the operational capabilities of the BATDD computing environment. It included training personnel in software measurement and maintenance techniques to insure high level system performance.

Specific tasks in this special study were:

- Assess current state-of-the-art of the system
- Investigate, design and develop new system tools and toolbox
- Transition technology by demonstrating the tools and prototypes, classroom presentations, and documentation development

10.24 Image Processing Technology for Heterogeneous Networks Systems

U.S. Army ARDEC/BATDD

Task 9554F 2600

The U.S. Army Research, Development and Engineering Center (ARDEC) at Picatinny Arsenal in Dover, N.J., is mission responsible for the repositories which house major weapon system Technical Data Packages, both hardware and software. Considerable documentation contained within a technical data package consists of graphical data, the majority of it in the form of engineering drawings. The management of these drawings is currently being transitioned from a microfilm-based system to one based on optical storage technology.

Recently ARDEC has been involved in programs aimed at developing advanced office automation systems within the context of open systems architecture that handle electronic forms generation and routing for networked systems. Although these systems currently handle only ASCII data, the goal of ARDEC is to include all graphic data associated with a technical data package in its routing for users in approving/concurring organizations to access, view and update data.

This effort analyzed designs and prototyped image storage, retrieval, and processing capabilities for wide area networks to include the following:

- Analyzed the performance of network software used to transfer large volumes of image data and identified deficient network software
- Applied software engineering methods to reconfigure the deficiencies
- Identified, recommended and prototyped software engineering tools and methods designed for the visually oriented user interfaces

- Identified and recommended appropriate software for data storage based on the latest magnetic and optical technologies.
- Assessed the maintainability of current ARDEC software systems involved in the image storage and retrieval process

10.25 Software Process and Software Metrics Program

U.S. Army Operational Test and Evaluation Center

Task 9554F 2650

One of the DACS' main functions is to transition software technology, such as software metrics, throughout defense organizations. The United States Army Operational Test and Evaluation Command (OPTEC) has, through the Software Test and Evaluation Panel (STEP), developed a set of four products to improve Operational Test and Evaluation within the Army. These products consist of a unified process, a guide to OT&E regulations, the User Functional Description, and a set of metrics.

OPTEC is now beginning the implementation of the STEP recommendations throughout the Army. This plan defined a program for providing technical support for the implementation of the STEP recommendations, particularly the STEP metrics. This task provided technical support to OPTEC's program for implementing the STEP initiative, concentrating on the software metrics developed by STEP. The DACS was joined in this effort by subcontractor, Dr. Amrit Goel of Computer Software Modeling Associates, Inc.

Technical support consisted of:.

- Supporting a conference to explain the STEP program to Army personnel
- Developing procedures and a methodologies for implementing the STEP metrics
- Developing an instruction program for the STEP metrics and for a prototype tool for storing and analyzing metric data
- Conducting seminars on the software metrics and prototype tool
- Documenting and analyzing comments and observations on the STEP metrics program obtained throughout this work.

10.26 IRSS/PAAS/ARCREF Code Conversion

U.S. Air Force Rome Laboratory (USAF RL/OC)

Task 9554F 2660

Rome Laboratory/OC has sponsored the development of the Interactive Radar Simulation System (IRSS), the Parametric Antenna Analysis System (PAAS), and the ARC Reflector Code (ARCREF). These systems provided comprehensive simulation capabilities for antennas, radar

and systems. A variety of analyses were made possible with these simulation capabilities. For example, trade-off studies can be done comparing different antenna or processor designs.

IRSS/PAAS/ARCREF currently runs on a VAX/VMS-based minicomputer. OC has begun adopting Sun workstations under various Graphical User Interfaces (GUIs) such as SunView and OpenWindows. This special study facilitated the transfer of this recent computer technology into OC by converting IRSS/PAAS/ARCREF to run on a SPARC-based (e.g. SPARCstation, Sun 4, etc.) architecture under OpenWindows and UNIX (SunOS).

Kaman Sciences transported parts of the IRSS and PAAS system to a Sun/UNIX environment under another program. This DACS effort began with those Sun/UNIX components as a baseline. Software engineering resource data was collected for this DACS special task. This data was used within an experiment for Kaman Sciences participation in the Rome Laboratory Software Quality Technology Transfer Consortium.

10.27 Battlefield Damage Assessment -Virtual Interface Prototype Data Collection

U.S. Army Smart Weapons Management Office

Task 9554F 2700

Kaman Sciences Corporation worked to develop a new software engineering technology to evaluate complex systems using knowledge-based computing environments, system engineering analysis, and virtual interactive prototyping techniques. The project began under IR & D funding and continued under a previously described special task through the DACS. The sponsors, the US Army Smart Weapons Management Office (SWMO) was specifically interested in the applicability of this technology by developing test case prototypes of a battlefield damage assessment for indirect fire smart weapons. To conduct a thorough and realistic evaluation of the technology, test data was required.

The objective of this task was as follows:

- Determine test data requirements
- Determine data collection techniques
- Collect actual target and damage signatures to evaluate the BDA/VIP in a test-bed environment.

This task provided the DACS a rare opportunity to use software engineering tools, techniques and methods in an operational environment critical to US war fighting capabilities.

10.28 Risk Assessment Prototype

U.S. Army OPTEC

Task 9554F 2800

This effort was developed to prototype a system which would provide software project managers and developers with knowledge-based support to manage software risks using the metrics

developed in the Army's STEP Program. The main objective of this effort was to develop a prototype knowledge-based system which will guide and help managers understand the status of software projects and make metrics based decisions. It was designed to help identify high risk items, find causes for the high risk status, and suggest resolution techniques. This effort was undertaken by the DACS and Dr. C.V. Ramamoorthy of the University of California at Berkeley.

A prototype Risk Assessment tool was developed using artificial intelligence techniques to include the use of

- Truth Maintenance Systems
- Expert System Shells

Documentation was also developed for the prototype and the commented code. It is anticipated that after follow-on expansion of this effort, this prototype may be incorporated into the U.S. Army's STEP Metric tool also prototyped by the DACS.

10.29 Rome Laboratory Software Quality Consortium Support

U.S. Air Force Rome Laboratory

Task 9554F 2850

This special study established the support parameters the DACS would provide to the members of the Rome Laboratory Software Quality Consortium.

The DACS performed the following Consortium support services as a part of this task:

- Developed a Pilot Application Plan (PAP)
- Supported and assisted Consortium members in the design of the pilot application plans for applying the Rome Laboratory Software Quality Framework (RSQF).
- Provided Quality Evaluation System (QUES) Support. Maintained the QUES and assisted Consortium members in its use
- Supported Consortium members in their use of the RSQF and associated data collection
- Assisted in the preparation of the Consortium Newsletter, planning and promotional activities, the technical interchange meetings, and site visits.
- Assisted in data gathering and analysis of data. Conducted user-surveys, analyzed lessons learned, assisted in RSQF Framework validation, and data repository, sanitization, interpretation, and statistical analysis.

10.30 Distributed Database/Parallel Processing Technology

U.S. Army ARDEC/BATDD

Task 9554F 2870

To increase the reliability and performance of its systems, the US Army's Research, Development and Engineering Center (ARDEC), is currently evaluating the concept of transitioning its database systems to operate in a distributed database environment. In an effort to provide faster, more reliable performance, the Battlefield Automation and Technical Data Division (BATDD) is planning to upgrade the Sun dataservers on ARDEC's wide area network to a multiprocessing model running Sun's new Solaris multiprocessing operating system.

BATDD required assistance in transitioning its mission critical software systems to embrace these two new technological advancements. This task supported BATDD's efforts in the transition of its mission critical software systems to the emerging software technologies of distributed database and parallel-processing with emphasis on the technologies of distributed database design, its use in the storage and retrieval of image data in a distributed database system, and the effects of parallel-processing within a distributed database environment.

Specific objectives of this task were as follows:

- Developed strategies and methods for transitioning current software systems to a distributed database/parallel processing environment; analyzed and critiqued the effectiveness of these strategies and methods through the use of prototypes
- Researched new or modified techniques for improving database performance in a distributed database/parallel-processing environment, translating these techniques into specifications for automated tools and developing prototypes of these tools
- Investigated, prototyped and evaluated methods for using distributed database technology on parallel-processing dataservers for the storage and retrieval of image data
- Produced a technical report analyzing the level-of-effort, difficulties encountered and solutions found in transitioning software systems from an environment of single processor machines to one of distributed processing on parallel machines

10.31 Certification of Reusable Software Components

U.S. Air Force Rome Laboratory (USAF RL/C3CB)

Task 9554F 2890

The purpose of this special study was to develop a certification methodology for designating various levels of confidence in the quality of reusable software components. Based on existing Rome Laboratory software quality assessment and test & verification technology, planned improvements in the technology as well as the Army's existing Reusable Ada Products for Information Systems Development (RAPID) certification criteria, a rigorous multi-level certification methodology was developed.

Levels of certification achieved were based on the results of applying each analysis technique/tool implementing these technologies. The task provided a vehicle for software developers/reusers to make intelligent choices regarding the selection of one component over another, or selecting reuse over original development. It also aided developers in understanding how to develop reusable software and attain the proper certification level for the components intended use. The certification and framework were incorporated into the DoD Software Warehouse.

State-of-the-art techniques and tools which can be immediately applied as a part of the certification process were identified.

The certification framework was developed and the possible levels of confidence defined along with specification of the criteria for each level.

What to store and how to store it was defined for the content and format of the information developed resulting from the application of the tools/techniques developed.

Joining the DACS in completing this technical area task was subcontractor Research Triangle Institute.

10.32 Software Metrics Tool Support

U.S. Army OPTEC

Task 9554F 2900

This project defined the tasks required in-order-to provide software engineering project metrics and management support for the US Army's Operational Test and Evaluation Center (OPTEC). The plan capitalized on the accomplishments of several earlier software engineering support tasks performed by the DACS for OPTEC to include the prototype development of an automated tool which supports the assessment of operational effectiveness and suitability of software early in the Continuous Evaluation (CE) process. Once again, Dr. Amrit Goel of Computer Software Modeling Associates supported the DACS in completing this task. Among other things, this task utilized and updated the prototype metrics analysis database tool. This task also capitalized on the activities pursued under the DACS task for the Software Process and Software Metrics Program.

This task provided technical and configuration management support to the US Army's Operational Test and Evaluation Center (OPTEC) program for implementing the Software Test and Evaluation Panel (STEP) metrics initiative by concentrating on the software metrics developed by STEP. DACS support consisted of the following activities:

- Prepared a STEP Metrics Clearinghouse Operational Concept Document.
- Evaluated selected requirements traceability tools for use in the STEP Metrics Program.
- Implemented STEP Data Item Descriptions (DIDs) in the prototype database.
- Customized a user interface for the STEP metrics

- Conducted demonstrations and present training workshops.

Modifications were made to the prototype STEP Metrics Database Tool. Modifications involved a Commercial-Off-The-Shelf (COTS) database tool operating in a UNIX and X-WINDOW environment.

10.33 Risk Management Using Knowledge-Based Techniques

U.S. Army OPTEC

Task 9554F 2920

This project provided continued software engineering support for phase 2 of an effort to provide metrics-guided risk management using knowledge-based techniques for the U.S. Army's Operational Test and Evaluation Command (OPTEC). Also identified were the tasks required to host the OPTEC metrics tool on a Kaman Sciences Sun computer for evaluation and demonstration purposes.

The main objectives of this special task were as follows:

- Enhance, install and prove the concept of the OPTEC Metrics Database Tool on a Kaman Sciences Corporation Sun Computer System. OPTEC supplied actual metrics data for test and evaluation in order to demonstrate the tool's capability for processing defined metrics sets. Quality and requirements metrics were targeted for initial development, followed by management oriented metrics.
- Developed prototype knowledge-based systems which guide and help *human* managers understand the status of software projects and make decisions during the metrics guided risk management of software projects. They identified high risk items, found specific causes for them, and suggested resolution techniques. With the help of knowledge-based systems human managers can identify high risk items and control them before they can cause serious problems in the project.

Technical support consisted of the following activities:

- Installed the OPTEC Database Tool on a KSC Computer.
- Loaded OPTEC supplied data on the restructured database - set up for STEP DIDs.
- Prepared database sub-tools for metric algorithm analysis.
- Created new menus for STEP data processing.
- Tested and evaluated database performance using actual STEP metrics.
- Completed tool documentation and prepared a user manual.
- Surveyed and studied literature in theoretical and practical aspects of risk management and metrics-based software project management.

- Studied applicability of metrics in the Army report for risk management
- Developed a prototype of knowledge-based tool for managing some major risk factors, experimented with them and evaluated them.
- Demonstrated the prototype and provided documentation for the prototype.

This technical area task was performed by members of the DACS staff and subcontractors Dr. Amrit Goel of Computer Software Modeling Associates, Inc. and Dr. C.V. Ramamoorthy of the University of California, Berkeley.

11.0 LESSONS LEARNED AND RECOMMENDATIONS

During this contract period, the initial period of operation of the Data & Analysis Center for Software (DACS) by Kaman Sciences Corporation, significant additions to the DACS database holdings were made. The software engineering bibliographic database (SEBD) was expanded substantially from the previous twelve years of DACS operation. The number of citations and abstracts increased in this three year period by almost 50 per cent. Similarly, the holdings for our software life cycle database (SLED), the software engineering research projects database (SERP) and the software engineering tools information database (SETI) also increased.

New sources of information were found and new methods of accessing those sources were developed and acquired. However, we found that to make our resources available and truly usable by the DACS user community, we must change the way we provide that information to others. Consequently, we recommend that the following areas and opportunities be considered for future adoption:

- Deliver "searches" in hardcopy and softcopy
- Dedicate substantially greater amounts of funds to obtaining source materials
- Integrate the output capability of the databases to deliver a product derived from each one of the databases where appropriate
- Explore opportunities for use of the National Technical Information System as a distributor of DACS products
- Offer the opportunity to copyrighted databases for the DACS to act as a distribution point for the data
- Increase the marketing activities associated with the DACS name and reputation
- Continue to vigorously pursue the acquisition of software engineering data from non-DoD sources such as NASA, the AIAA and corporate entities.

We must also work to increase the reputation and recognition of the DACS in all areas of the DoD and other governmental activities. Participation at high level activities such as the DoD Software Strategy Planning Forum, and with the Navy in the Next Generation Computer Resources Program have paid dividends to the DACS. Increased participation with major technology organizations and associations such as the IEEE and ACM will continue that trend. Submission of papers and presentations to journals and conferences will help as well.

Finally, making better use of our subcontractors breadth of technical experience will add to DACS capabilities and reputation as well as to our recognition in non-traditional markets.

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